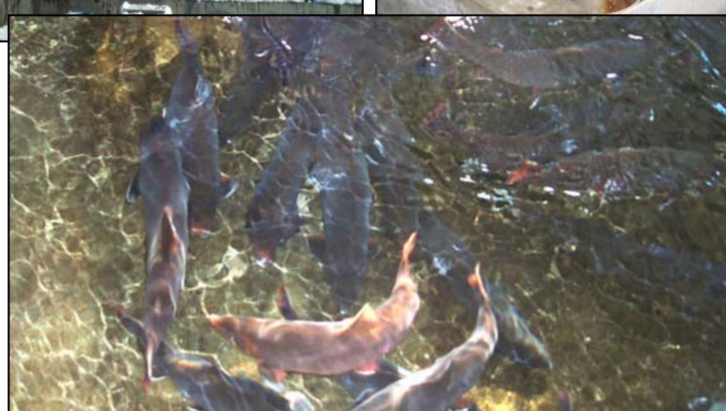
FISHERIES BIOENGINEERING SERVICES FOR HATCHERY EVALUATION AND WATER USE/WATER TREATMENT RECOMMENDATIONS

FORT RICHARDSON STATE FISH HATCHERY ALASKA DEPARTMENT OF FISH AND GAME SPORT FISH DIVISION



FEBRUARY, 2002

PREPARED BY:
THE CONSERVATION FUND
FRESHWATER INSTITUTE

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EXECUTIVE SUMMARY

The Fort Richardson State Fish Hatchery (SFH) produces chinook salmon, coho salmon, rainbow trout, arctic char, and arctic grayling for sport fish management and enhancement throughout South central and Interior Alaska.

The water source for Fort Richardson SFH is primarily well water. However, the 3,500–4,500 gpm of well water that is available is only about half of the original 8,700 gpm design flow for Fort Richardson SFH, which has been a major constraint to fish production at this hatchery. Fort Richardson SFH uses heat exchangers to extract waste heat from the adjacent Fort Richardson power plant effluent flow. This heat recovery process can heat up to 3,000 gpm of 2–7ºC well water to 14ºC. Fort Richardson SFH has been able to meet their fish production plan because of the 10–14°C water temperatures that can be routinely achieved using the waste heat from the fort's power plant. Unfortunately, the Fort Richardson power plant is scheduled to close in September of 2003 as the base transitions away from a centralized heating system and develops a distributed heating system throughout the base to achieve better energy efficiencies. Without the opportunity to heat the well water supply, nearly all of the fish production will have to rely on ambient well water temperatures. However, Fort Richardson SFH's current production levels cannot be maintained at ambient well water temperatures.

This report has identified three primary actions that need to be considered in order to allow the Fort Richardson SFH to meet the needs identified within the existing conditions section of this report:

- Need #1. Prepare for the loss of the Fort Richardson power plant waste heat in September 2003.
- Need #2. Prepare for the possible loss of the Fort Richardson dam.
- Need #3. Improve the Fort Richardson SFH facilities (safety, biosecurity, water and oxygen use efficiency).

Each of the primary needs include 2–6 recommended options. Implementation of any of these option combinations would maintain current fish production goals. However, when all actions proposed within this report are considered, then Option (5) of Need #1 is probably the best choice, i.e., abandon Fort Richardson SFH and build a new state-of-the-art hatchery at a better location.

The Alaska Department of Fish and Game would have to make a considerable investment, up to $5 million, to upgrade the Fort Richardson SFH as described in this report. However, the possible loss of power plant waste heat at the Elmendorf SFH must also be considered. The U.S. Air Force is currently evaluating whether the Elmendorf Air Force Base power plant should remain in operation or be shut down. The decision to remain operating or close the Elmendorf base's power plant will not be made until late 2002 and it would take the base at least three years to develop a distributed heating system. Therefore, Elmendorf SFH may also be facing lost production capacity by 2005 if their inexpensive source of waste heat is lost. Even when considering the options proposed here, the fish production requirements of the Alaska Department of Fish and Game could not be met if the waste heat supplied to the Elmendorf power plant was also lost. In this event, it is recommended that the Alaska Department of Fish and Game consider closing either the Fort Richardson or Elmendorf SFH and building a new hatchery to handle all production that cannot be met by the remaining hatchery. This conclusion is nearly inescapable if both hatcheries end up losing their source of inexpensive waste heat. It is recommended that a new hatchery would be designed to operate on a well water supply and would use tank-based recirculating systems to minimize water use, heat input requirements, and the environmental impact on the receiving water. It is estimated that a new state-of-the-art hatchery would cost $9–16 million. If this kind of capital funding can be obtained, it is recommended that this new hatchery be built at an inland location with convenient access to stocking sites. The location selected for a new hatchery would have to include suitable well water resources (at least 1,000 gpm of high quality ground water), good road access, 3-phase power, natural gas, and telephone service, as well as available public sewer connections if septic tanks and leach fields are not permitted.

It is our opinion that continued operation of either Fort Richardson or Elmendorf SFH is essential to maintain the public education and outreach that is achieved when approximately 10,000 visitors per year visit the Elmendorf SFH. The ease of access to Elmendorf SFH is a major reason to keep Elmendorf SFH open and close the Fort Richardson SFH in the event that both hatcheries lose their access to inexpensive waste heat.

REVIEW OF EXISTING CONDITIONS

The existing conditions were assessed using information gathered during a site visit to Fort Richardson State Fish Hatchery (SFH) by Brian Vinci and Steven Summerfelt on October 22–23, 2001.

Hatchery Background Information

Contacts

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Staffing

Fort Richardson SFH has nine full-time employees. One of these employees is off-site a majority of the time doing fish stocking and remote egg takes. Seven of the employees work in fish culture.

Location

Fort Richardson SFH is located on the Fort Richardson Military Reservation approximately 15-minutes from downtown Anchorage. The hatchery is adjacent to a base recreation park and between the Fort Richardson power plant and Ship Creek.

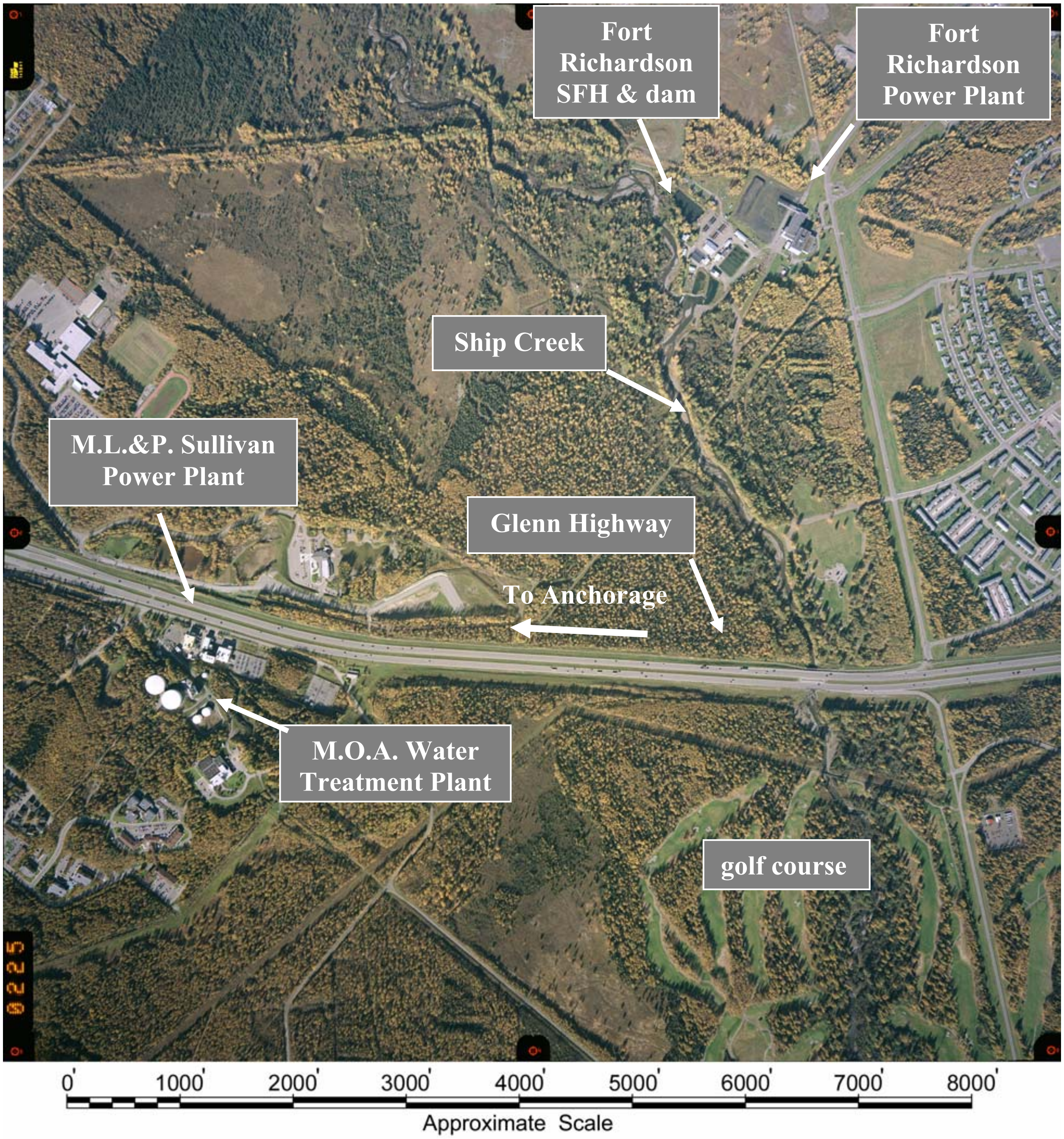

Figure 1. Aerial photo showing Fort Richardson SFH in relationship to other nearby land uses.

Hatchery Mission/Overview

The Fort Richardson SFH produces chinook salmon, coho salmon, rainbow trout, arctic char, and arctic grayling for sport fish management and enhancement. Once released, these fish are intended to provide increased fishing opportunities, reduce fishing pressure on wild fish stocks, and provide diversity in sport fisheries throughout South central and Interior Alaska. Over 400 sites were scheduled for stocking in 2000, requiring some 100 stocking trips (2000 Annual Management Plan, Alaska Department of Fish and Game). The majority of stocking is in landlocked lakes or lakes with minimal opportunity for stocked fish to leave the water body. Anadromous salmon smolts are released at fifteen different sites with the intention that these fish will mature into adults and return from the ocean to create fishing opportunities for sport fishermen.

Brochures/Historical Publications

The Alaska Department of Fish and Game, Sport Fish Division, has developed the following reports that are directly relevant to the hatchery's management and strategic planning:

- Hatchery Production Strategic Plan (draft under development)
- 2000 Annual Management Plan: Elmendorf and Fort Richardson State Fish Hatcheries (April 2000)
- Statewide Stocking Plan for Recreational Fisheries 2001 (January 2001)

A report discussing the feasibility of developing additional water sources for Fort Richardson SFH was prepared by F. Robert Bell and Associates (Anchorage, Alaska) for the Municipal Light and Power company in August of 1991.

Minutes from the Anchorage Waterways Council's 2001 Annual Meeting include a transcript of remarks by Lance Trasky of the Alaska Department of Fish and Game that clearly states the influence that the four dams have had on fish passage and salmon returns in Ship Creek. This transcript also implies the position of the Habitat Restoration Division of the Alaska Department of Fish and Game and of the Anchorage Watershed Council on restoration of Ship Creek.

<u>Surrounding Land Use and Watershed Issues</u>

Key Watershed Issues

Dams Limit Fish Passage in Ship Creek

There are four dams/spillways currently on Ship Creek. Three are associated with power plant water supplies and one with a municipal drinking water supply.

There is a large dam to impound cooling water at the inactive Chugach Steam and Electric power plant that is located within one mile of where Ship Creek flows into Cook Inlet (Figure 2). The Chugach Dam is approximately 8 ft high and was constructed within the intertidal area of Ship

Creek. The Chugach Dam has a fish ladder that was constructed in 1970. Because the Chugach Dam replaced most of the estuary, salmon smolts that pass down the fish ladder go immediately from a freshwater environment to a saltwater environment and adult salmon entering the ladder go immediately from a saltwater environment to a freshwater environment. Some claim that this forced and abrupt transition makes this the most destructive dam to anadromous fish on Ship Creek, as adult salmon preparing to migrate upstream and salmon smolt migrating to the ocean have little time to adapt to the new salinity levels. This dam may have eliminated smelt and white fish in Ship Creek. However, Nation's Energy Company had expressed an interest in re-activating this power plant and utilizing this dam.

There are also two dams/spillways at each SFH. These dams were built to supply cooling water for the power plants built at the Elmendorf Air Force Base and the Fort Richardson Military Reservation. The hatcheries were built next to the power plants to take advantage of the waste heat discharged from these power plants. The Elmendorf Dam was initially built in 1942 and is located approximately 2.3 miles from the mouth of Ship Creek. The Elmendorf Dam was rebuilt most recently in 1983 as a two-tiered, 12 ft high, sheet-pile dam. This dam has a two-tiered fish ladder that has never been opened and virtually all fish passage upstream of the dam has been blocked except during high water events when a few king salmon can pass the two-tiered dam and spawn upstream. One proposed plan to restore fish passage in Ship Creek calls for rebuilding the fish ladder at Elmendorf SFH in order to enhance salmon passage while also providing an opportunity for public education and outreach at the hatchery (See the Identified Needs and Recommendations section for more details). The Fort Richardson Dam was built in 1953 and this dam may be low enough for adult salmon to jump, if the salmon were able to migrate that far up Ship Creek.

The fourth dam on Ship Creek was built in 1941 and rebuilt in 1953 approximately 12 miles from the mouth of Ship Creek. This large 40 ft tall dam was built in order to supply drinking water to Anchorage and to both military bases, but is now only being used to supply water to both military bases.

These four dams on Ship Creek have impacted the natural fisheries in Ship Creek by:

- restricting and blocking fish passage;
- reducing the intertidal mixing area and the size of the estuary zone at mouth of Ship Creek;
- producing man-made pools that have eventually filled in with sediment and that over the years have limited the transport of sands and gravels to the mouth of Ship Creek at Cook Inlet, which has had some affect on this estuary environment.

Also, three of the dams were constructed to supply power plants with cooling water flows that when discharged to Ship Creek create a zone of unnaturally warm water that may be a barrier to fish passage and also changes environmental conditions in Ship Creek.

The local watershed group, the Anchorage Waterways Council, would like to see the first three dams removed from Ship Creek to restore the creek to conditions that would support more natural salmonid fisheries.

The habitat division of the Alaska Department of Fish and Game is also in support of dam removal. Ship Creek is the second most popular fishery in Alaska and several private non-profit, federal, or state agencies may be willing to supply money and/or manpower to restore the Ship Creek drainage to more natural conditions.

Snowmelt and Ice Breakup

Snowmelt and ice breakup during the spring thaw causes large increases in Ship Creek flow, depth, and water turbidity.

Stakeholders

The local watershed group is the Anchorage Waterways Council (AWC).

Anchorage Waterways Council
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awc@alaska.net
Office Location: 619 E. Ship Ave, Suite 319
Executive Director: Holly Kent

The AWC is based in Anchorage and has an office and paid staff including an executive director. In 2000 the AWC had $121,000 in income with the majority of funds coming from the USEPA 319 grant program ($76,000). The AWC presents their mission on their world wide web site (http://www.anchwaterwayscouncil.org/index.htm) as the following:

> The Anchorage Waterways Council (AWC) is a non-profit organization comprised of residents who believe that Anchorage's waterways and related habitats are a valuable resource. The AWC organized following the first creek cleanup effort in 1984.
>
> The scope of the AWC is municipality-wide, from Peter's Creek to Portage Glacier and includes all types of waterways -- rivers, lakes, streams and wetlands. The AWC is committed to preventing further degradation of our waterways, enhancing our waterways through public involvement and education, ensuring safe and productive aquatic and riparian habitat for fish and wildlife, and monitoring activities that affect our waterways.

In partnership with other local environmental groups the AWC started a water quality monitoring program in 1999. This Citizen's Environmental Water Quality program relies on a network of volunteers to take physical and chemical baseline data in seven creeks in the Anchorage area. There are plans to expand the program to cover more water bodies and also perform bioassessment studies.

In addition to the Citizen's Environmental Water Quality program the AWC sponsors creek clean-ups, publishes a quarterly newsletter for its members, and performs environmental education and outreach through sponsored-events like its annual meeting. The AWC also has an active program that seeks to remove the three lower dams from Ship Creek. In November 2001 a coordinator was hired to lead the AWC efforts to get the lower dams removed from Ship Creek.

Membership in the AWC costs $20 for an individual membership, $30 for a family membership, and $125 for a basic corporate membership.

Changing Land Use

There is little or no apparent agricultural activity in Fort Richardson SFH's general vicinity.

There are no major industrial plants located upstream of the hatchery and polluting discharges into Ship Creek are not likely a problem. However, runoff from two golf courses and the Elmendorf flight line can impact the watershed.

There are two golf courses located on land adjacent to Ship Creek. One golf course is located upstream of the hatchery and the other golf course is located downstream of the hatchery.

Fort Richardson SFH is located on the military reservation near a recreational park. Development on the military reservation is limited, however the hatchery is located just outside of the city of Anchorage. It is unclear whether the military would further develop the area around the hatchery, but it seems unlikely.

The Fort Richardson Military Reservation's power plant is scheduled to close in September of 2003 and will likely be demolished.

There is a drinking water reservoir located on Ship Creek upstream of the Fort Richardson SFH. The U.S. Army owns and operates this upper-most dam. The U.S. Army will probably wish to continue using the upper-most dam as a drinking water source.

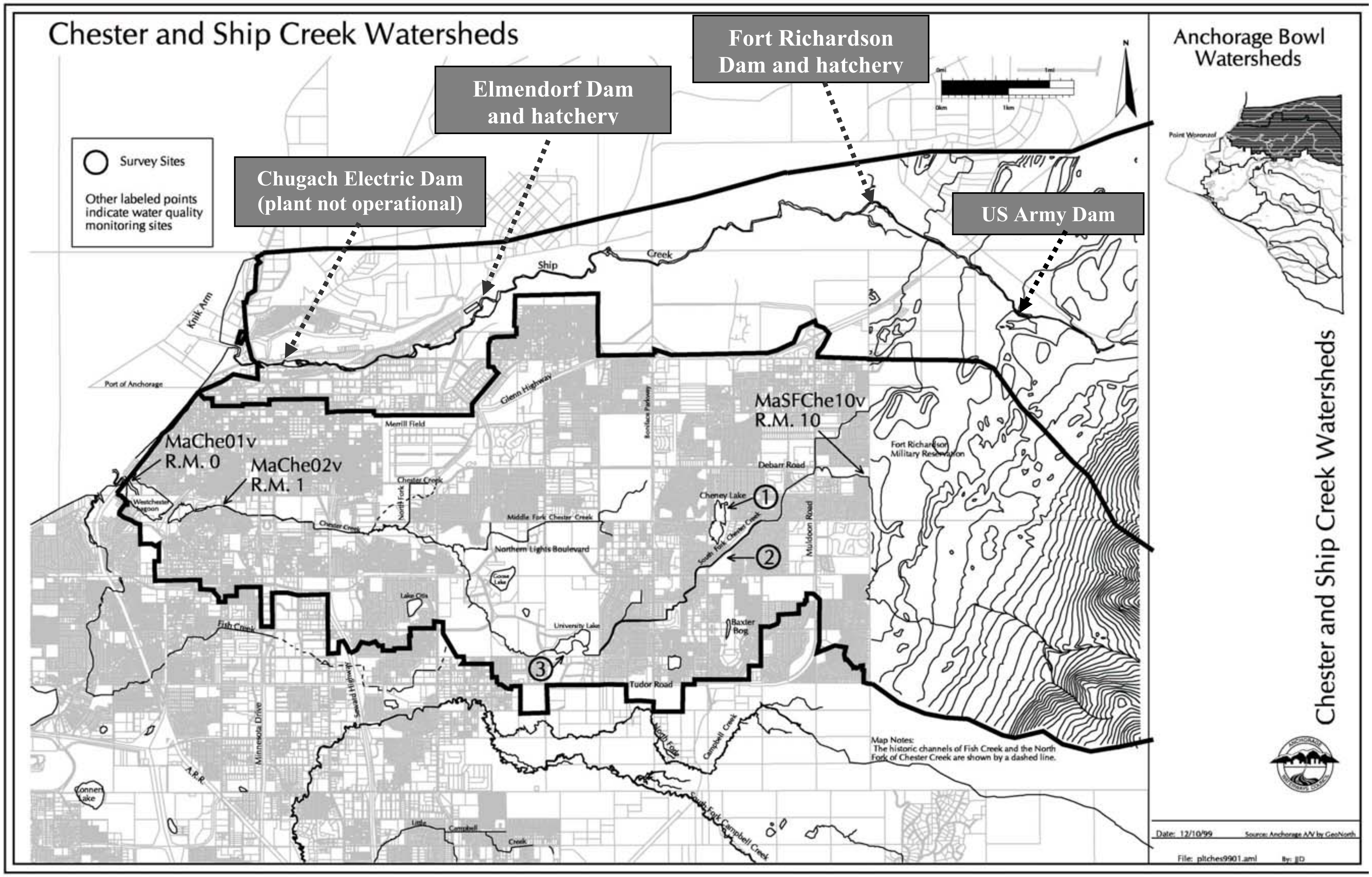

Figure 2. Ship Creek has four dams within its last 12 miles. The Elmendorf Dam blocks salmon from migrating further up Ship Creek.

Water Supply

Water Source

Well Water

The water source for the Fort Richardson SFH is primarily well water, with 21 wells in operation. Twenty of the wells are shallow (approximately 25 ft deep) and one well is deep (approximately 125 ft deep). Ten of the wells are in close proximity to the hatchery. The hatchery also purchases well water from Fort Richardson.

All well water supplies are combined into a blended water sump. These cold-water sump temperatures have been recorded (Figure 3) and show a seasonal temperature change of approximately 5ºC. Up to 3,000 gpm of well water is heated from an ambient temperature of 2–7ºC to approximately 14ºC using waste heat from the Fort Richardson power plant.

It is possible that the Fort Richardson SFH's well water supply would be seriously compromised if the power plant spillway were removed, because this action could lower the piezometric pressure above the well pump intakes.

Additionally, the hatchery has the capacity to use Ship Creek water in an emergency situation.

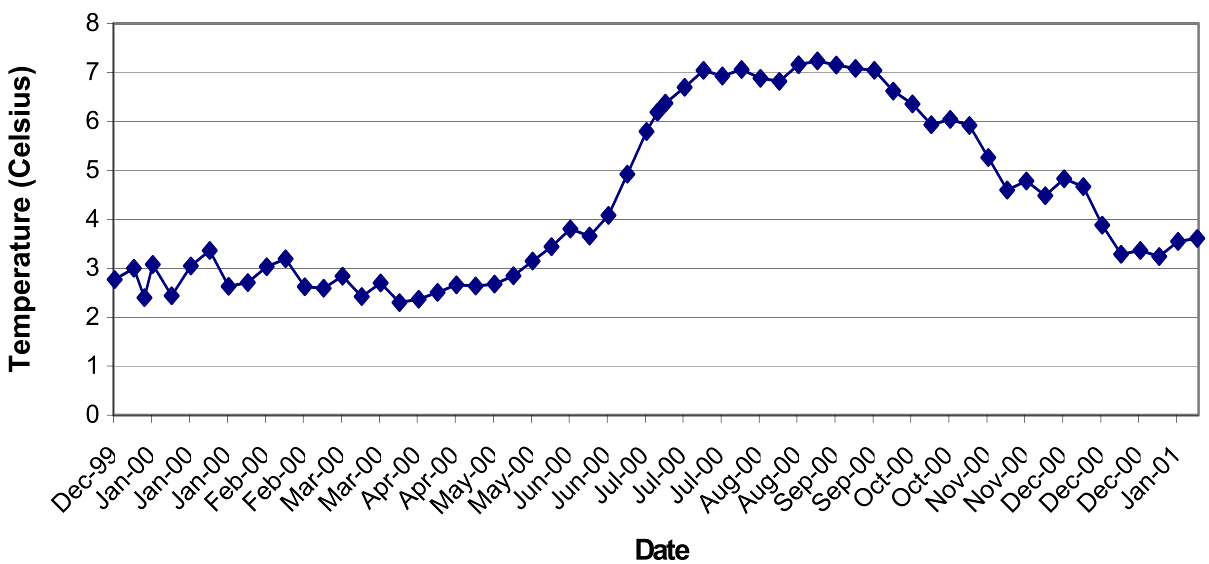

Figure 3. Blended well water supply temperatures from December 1999 to January 2001. The temperature of the blended well water supply ranges from just over to 2ºC to just over 7ºC.

Power Plant Cooling Water Usage

The Fort Richardson Military Reservation's power plant (Figure 4) takes its cooling water from Ship Creek and then Fort Richardson SFH extracts waste heat from the power plant's effluent flow using heat exchangers. The heat exchangers are used to raise the temperature of approximately 3,000 gpm of water from an ambient temperature of 2–7ºC to about 14ºC before this water is supplied to the hatchery's fish culture systems. The Fort Richardson power plant is scheduled to close in September of 2003 as the Army transitions away from a centralized heating system and develops a distributed heating system throughout the base to achieve better energy efficiencies. Without the opportunity to heat the well water supply, nearly all of the hatchery's fish production will have to rely on ambient well water temperature. However, Fort Richardson SFH's current production levels cannot be maintained at ambient well water temperatures. Similarly, Elmendorf SFH is reliant upon use of waste heat generated by the Elmendorf Air Force Base's power plant and the Air Force is evaluating whether this power plant should remain in operation or be shut down. The decision to remain operating or close the Elmendorf Air Force power plant will not be made until late 2002 and it would take the Elmendorf Air Force Base at least three years to develop a distributed heating system. Therefore, the Elmendorf SFH may also be facing lost production capacity by 2007 if their inexpensive source of waste heat is lost.

Figure 4. The Fort Richardson Military Reservation's power plant is located adjacent to Fort Richardson SFH and uses Ship Creek water for cooling purposes. Some of the waste heat from the power plant's effluent is captured by the hatchery to heat up to 3,000 gpm of its well water supply.

Well Water Quality

Only limited data is available: pH is approximately 7.48, hardness is approximately 76 mg/L (as $CaCO_3$), and aluminum is approximately 26 µg/L.

The well water temperature varies from 2–7ºC over the course of the year, which indicates that the shallow aquifer is influenced by surface water. However, the Fort Richardson SFH staff indicated that the turbidity of the well water always remained low, so turbidity is not influenced by Ship Creek turbidity events. The fluctuation in well water temperature does raise a concern with the assumed biosecurity of the well water supply, because this well water supply might also become contaminated with pathogens found in the surface water.

Well Water Quantity

The Fort Richardson SFH was designed to operate on a mix of heated and cold-water flows that totaled 8,700 gpm. However, the well field has never been able to supply enough water to operate at this design flow, which has been a major issue for fish production. The Fort Richardson SFH can obtain a maximum 3,500–4,500 gpm of well water and requires this much flow to operate during most of the year (Figure 5). This includes January–March when the aquifer is at its lowest levels. The minimum water use is typically in October when water flow can drop as low as 2,500 gpm. The Army well has the maximum well output of 675 gpm and the minimum well output comes from Wells #5 and #8, each yielding approximately 50 gpm.

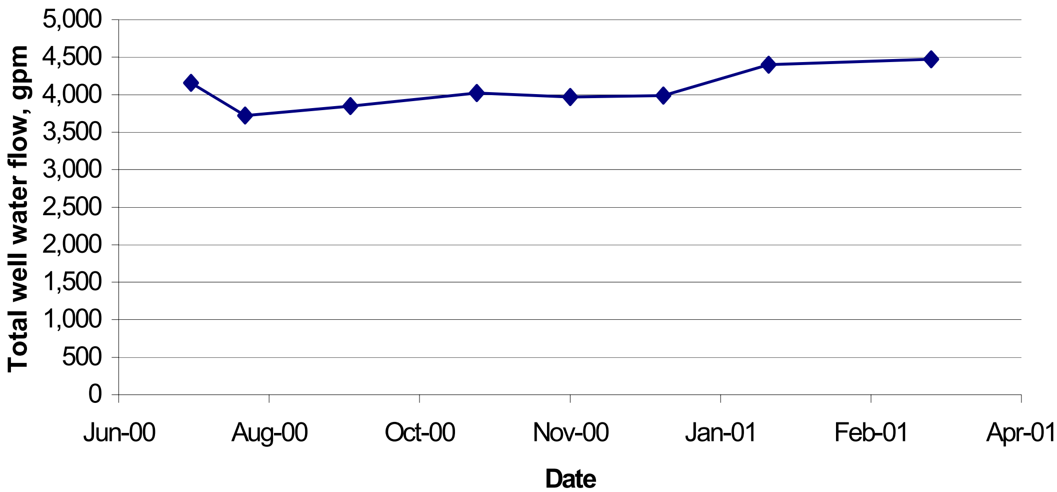

Figure 5. Recent well water production rates reported at Fort Richardson SFH from July 2000 to March 2001.

Ship Creek Water Quantity

The U. S. Geological Survey (USGS) maintains an active stream-gage station on Ship Creek located upstream of Fort Richardson SFH. The USGS station 15276000 is located at latitude N 61º 13' 32" and longitude W 149º 38' 06". The datum of the stream gage is at 490 feet above sea level. Figure 6 shows the location of this station.

a. b.

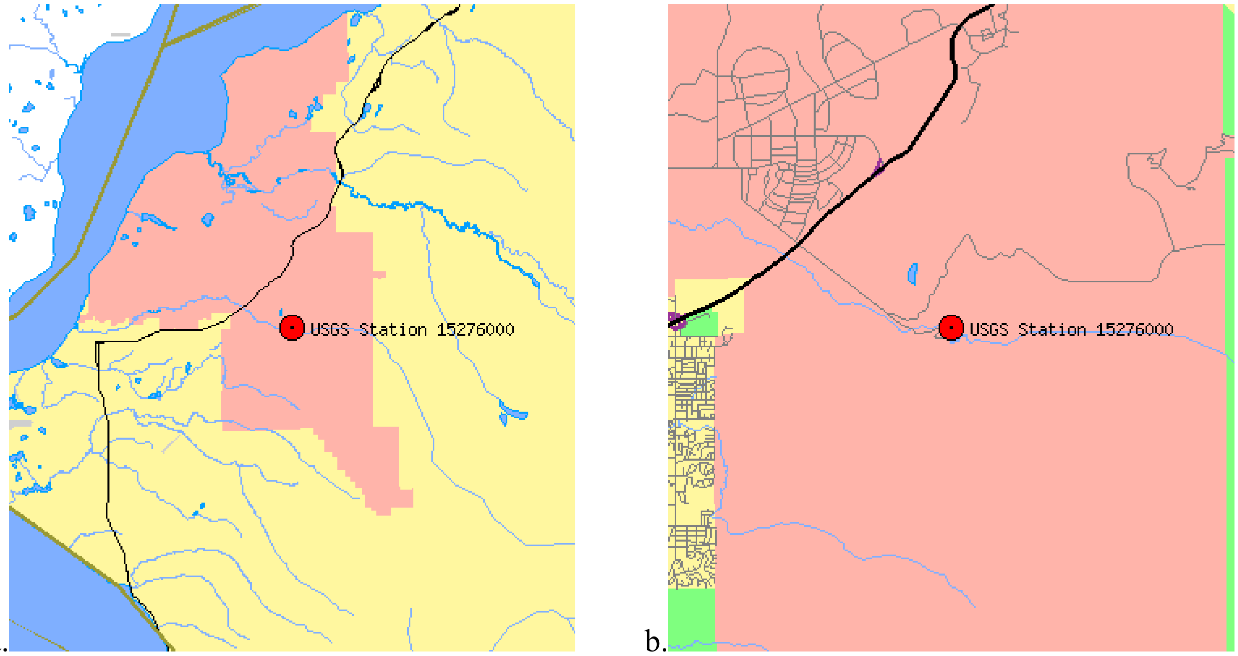

Figure 6. Location of the Ship Creek USGS Stream-Gage Station: a. wide view and b. close-up.

Data from this stream-gage station are available for stream flow of Ship Creek. Ship Creek displays a consistent yearly pattern of stream flow that is discussed in the next section.

Ship Creek water is seasonal in quantity and temperature. The USGS stream-gage station shows that the maximum flow of over 450 cubic feet per second (cfs) occurs in June and flow declines until it reaches a minimum of 16 cfs in March. Water flow is still only 24 cfs in April and 168 cfs in May before the maximum in June. Figure 7 charts the monthly mean stream flow from the USGS data on record (1946–1999) showing this average yearly fluctuation. Figure 8 shows USGS daily stream flow data for the period from 1994–1999, which illustrates the consistency of this yearly fluctuation.

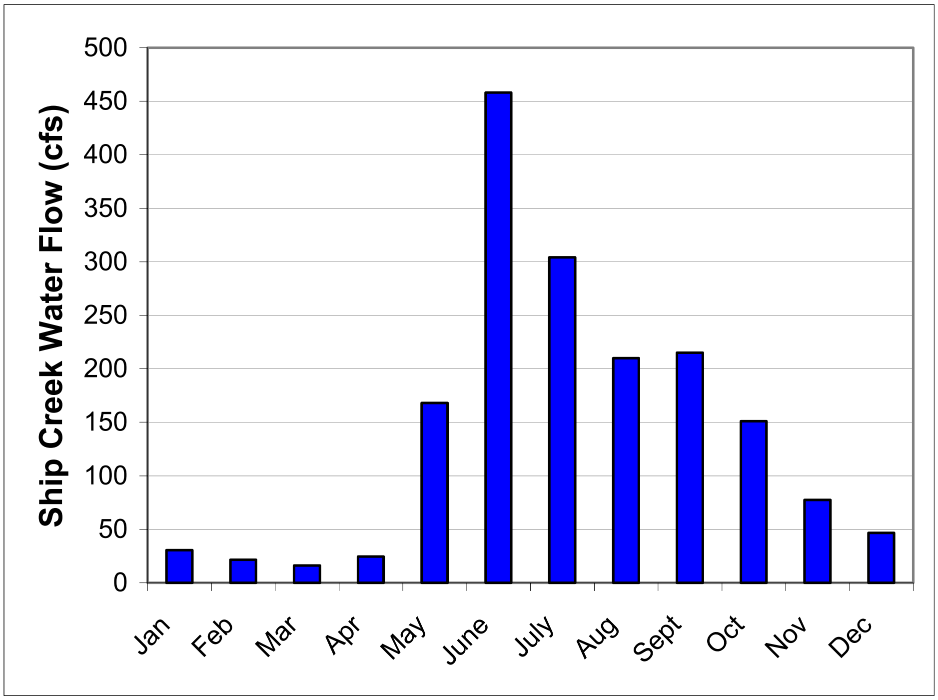

Figure 7. 1946–1999 monthly mean Ship Creek flow in cubic feet per second (cfs).

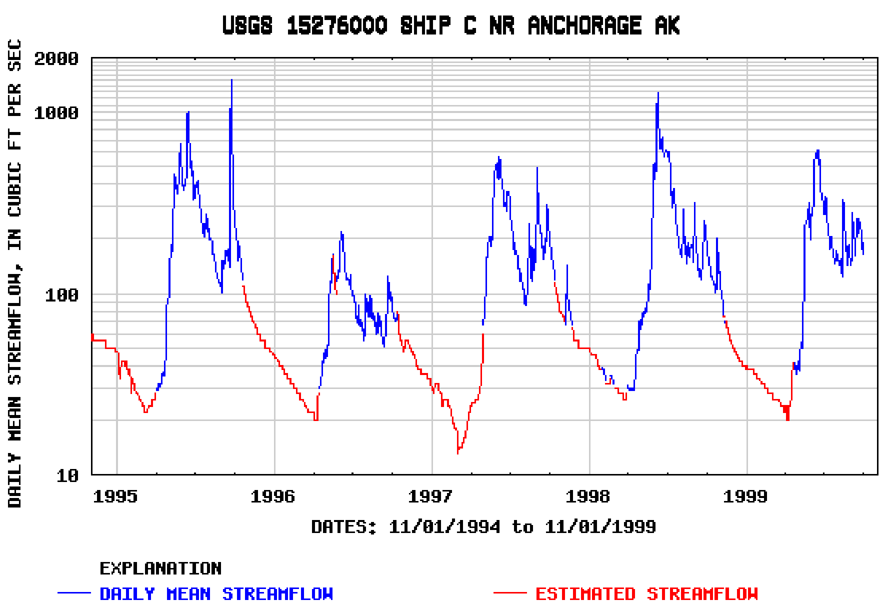

Figure 8. 1995–1999 daily mean Ship Creek flow in cubic feet per second (cfs).

Ship Creek Water Quality

Ship Creek also fluctuates in temperature over the course of a year as would be expected for a flowing surface water. Elmendorf SFH staff estimate that the temperature varies from 0.5ºC in December, January, and February to 10.2ºC in July. Figure 9 shows the estimated monthly mean Ship Creek water temperatures.

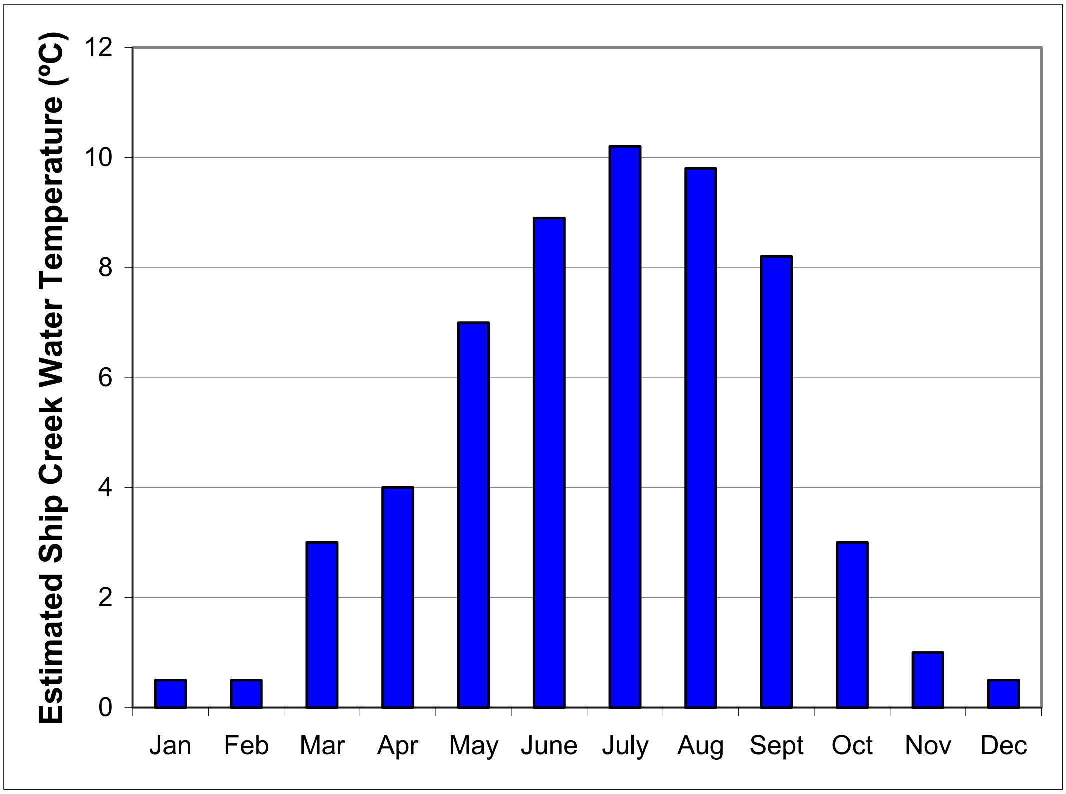

Figure 9. Estimated monthly mean Ship Creek water temperature in degrees Celsius.

Water quality records for Ship Creek exist from a sampling event in April, 1991. In this water quality monitoring event Ship Creek water was sampled from five locations: above Fort Richardson SFH (SP #1), at the effluent from Fort Richardson SFH (SP #2), between Fort Richardson and Elmendorf SFH (SP #3), above the golf course adjacent to Elmendorf SFH (SP #4), and below the golf course (SP #5). Figure 10 illustrates the approximate sample point locations in relation to Fort Richardson and Elmendorf SFH. Table 1 presents the results of the water quality analysis. The data shows a marked increase in conductivity (88%), alkalinity (143%), and magnesium (293%) after Ship Creek passes the Air Force base north/south runway. Additionally, nitrate/nitrite increases 3,100% after Ship Creek passes the golf course.

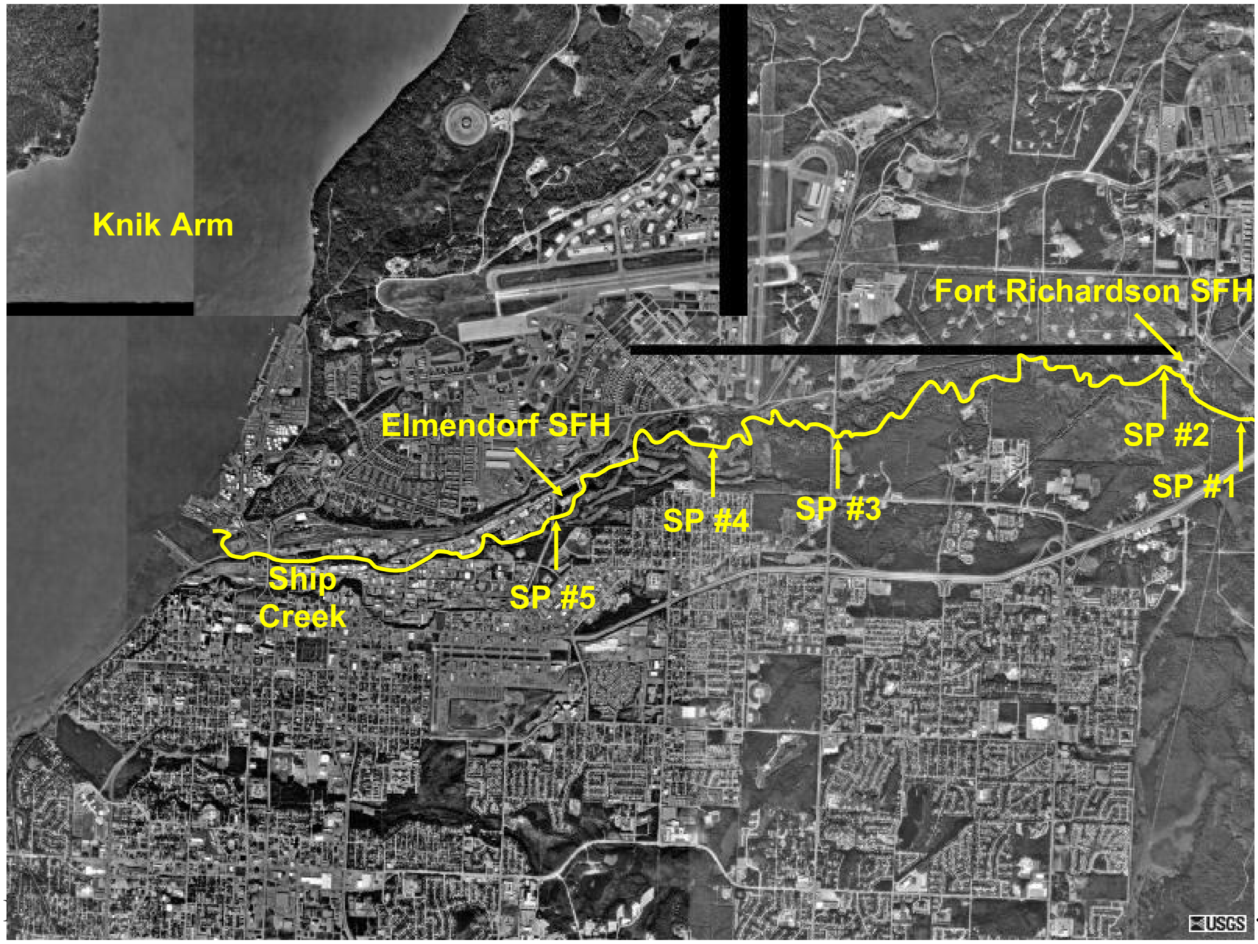

Figure 10. Approximate location of water quality sample points within Ship Creek in April 1991.

Table 1. Water quality analysis for Ship Creek from April 1991.

Parameter	SP #1	SP #2	SP #3	SP #4	SP #5
Conductivity (µmhos/cm)	160	180	163	306	335
pH	7.7	7.6	8.8	7.2	7.9
Alkalinity (mg/L)	61	65	60	146	141
Turbidity (NTU)	2.0	1.8	1.4	0.6	0.3
Color (Pt units)	6	4	5	3	3
Calcium (mg/L)	20.2	23.8	21.1	21.2	30.8
Magnesium (mg/L)	3.7	3.0	3.0	11.8	9.7
Total Iron (µg/L)	42	36	30	29	32
Total P (µg/L)	2.4	174.4	33.9	2.7	1.5
TAN (µg/L)	4.4	268.9	12.2	25.3	5.9
Nitrate/Nitrite (µg/L)	298.6	378.2	326.1	113.8	3668
Reactive Silicon (µg/L)	3639	3558	2591	6320	5620

Treatment Processes

Building for Influent Water Heat Exchange and Aeration

All well water is directed to a sump in the bottom of the influent water heat exchange and aeration building. The influent water heat exchange and aeration building was installed in 1981. The heat exchange and aeration building is used to extract waste heat from the Fort Richardson power plant effluent to raise the temperature of some of the well water to 14ºC and to aerate and degas any super-saturated levels of dissolved gases from both the ambient well water and heated well water supplies. A process flow drawing of the components found in the heat exchange and aeration building is shown in Figure 11. The heat exchange system uses one pump, with an identical back-up pump that has been plumbed in parallel, to send cold well water to the cold side of two plate and frame heat exchangers that have been plumbed in parallel for extracting heat from the heated power plant effluent flow (Figure 12). Another pump with an identical back-up pump that has been plumbed in parallel sends a portion of the heated power plant effluent flow (approximately 20ºC) through the hot side of the heat exchangers (Figure 13). The heated well water exiting the heat exchangers is directed to a separate warm water sump (Figure 11). One or two additional pumps with an identical back-up pump that has been plumbed in parallel are used to lift water from the warm water reservoir (Figure 14) to a manifold feeding nine aeration columns (Figure 15). Each rectangular aeration column is 2 ft wide by 2 ft long and 12 ft tall (Figure 15). These nine columns discharge into a shallow 3 ft deep collection sump located on the roof of the heat exchange and aeration building (Figure 16) and this sump provides the head pressure to supply this water to all of the fish culture locations. The columns are located outside on the roof of the influent water heat exchange and aeration building. The cold well water supply can also be pumped from the cold water sump to six separate aeration columns located over a separate supply sump on the roof of the heat exchange and aeration building. These six columns discharge into another shallow 3 ft deep collection sump located on the roof of the building and this sump provides the head pressure to supply cold water to all of the fish culture locations at the hatchery. The pumping rates to the aeration columns are manually adjusted using variable speed motor controllers. Ideally, adjusting the flow rate coming from each of the variable speed pumps can maintain a relatively constant water depth in each of the roof-top supply sumps as long as the demand for water at the fish culture locations remains constant. In reality, it is sometimes difficult to manually adjust the pumps so that they maintain a constant water depth in the roof-top supply sumps without producing a significant overflow of warm water back to the lower warm water sump. The overflow pipe is a 30 inch diameter up-turned standpipe (Figure 17) and the weir circumference allows for a large overflow even at a low weir water level. A different problem would occur if the water level in the roof-top sumps dropped too low, because air could then be suctioned into the pipes that supply the warm water or cold water to the fish culture systems. Air suctioned into the pipes would create high gas pressures and the potential for gas bubble trauma in the fish, as well as possible air lock in the pipeline. To avoid these problems, the PID control routine was set to operate with a fair amount of overflow. This overflow is returned back to the lower pump sump.

The aeration columns on the roof of the heat exchange and aeration building are typically capable of lowering total gas pressures to approximately 102% saturation. It was noted that the aeration columns were unable to consistently degas dissolved nitrogen to levels sufficient to protect some of Fort Richardson SFH's hyper-sensitive fish from signs of gas bubble trauma.

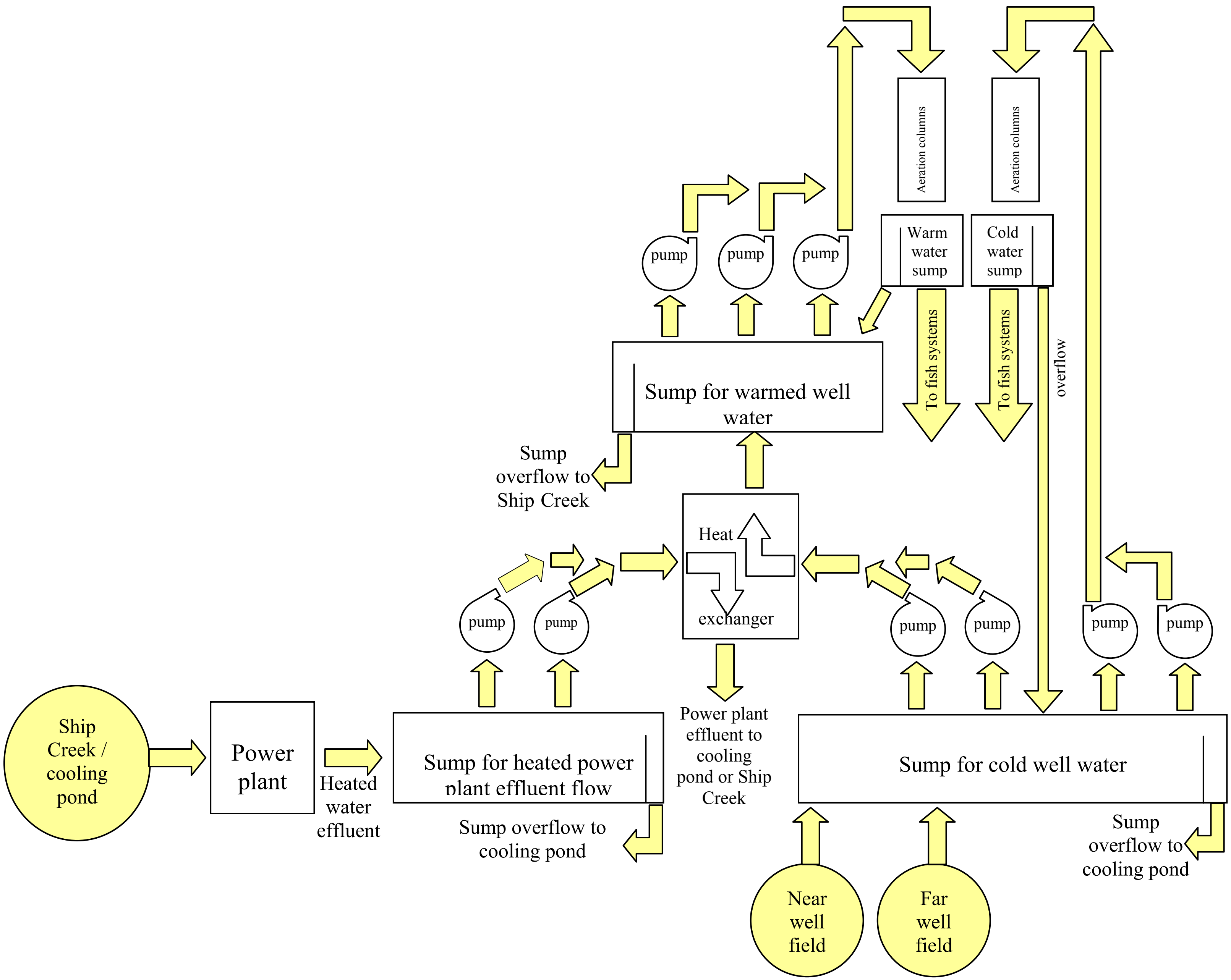

Figure 11. Process flow diagram for influent water treatment at Fort Richardson SFH.

Figure 12. The heat exchange system uses one pump with an identical back-up pump that has been plumbed in parallel to send cold well water to the cold side of two plate and frame heat exchangers that have been plumbed in parallel for extracting heat from the heated power plant effluent.

Figure 13. One of two plate and frame heat exchangers used to transfer heat from the heated power plant effluent to the cold well water used by Fort Richardson SFH.

Figure 14. Vertical turbine pumps lift heated well water from the warm water reservoir to a manifold feeding nine aeration columns located on the roof of the well water treatment building.

Figure 15. Each of the twelve aeration columns is 2 ft wide by 2 ft long and 12 ft tall.

Figure 16. Each of the aeration columns discharges into a shallow 3 ft deep collection sump that is located on the roof of the heat exchange and aeration building and this sump provides the head pressure to supply water to all fish culture locations.

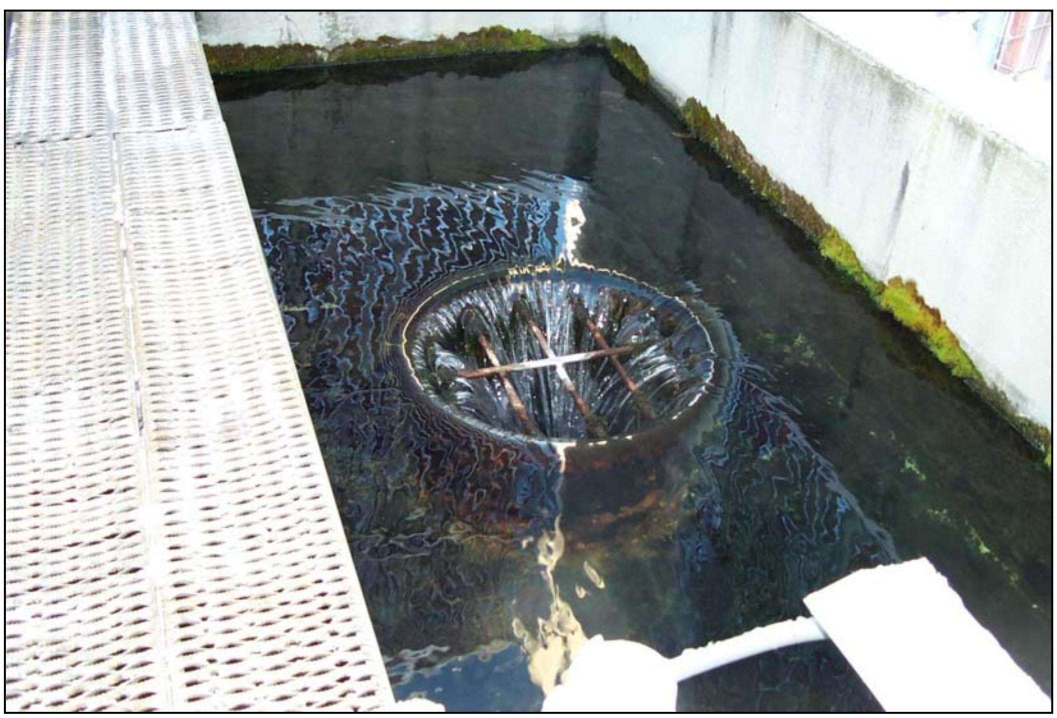

Figure 17. A 30 inch diameter standpipe collects warm water overflow from the roof-top sump and returns this flow to the warm water sump.

Facility Design

The site plan for the Fort Richardson SFH is shown in Figure 18. Major features of the hatchery include:

- an influent water treatment building that is used to heat and aerate the well water supply before it is sent to the fish culture systems;
- the Broodstock Development Center, which includes a building and an outdoor concrete raceway system;
- two additional outdoor raceway systems;
- a building for indoor raceway culture and egg incubation;
- a visitor's center;
- a main office;
- a shop building;
- one larger and one smaller settling pond that are used to treat the water flowing out of the fish culture systems before it is discharged to Ship Creek; and
- three residences for hatchery staff to live on-site.

Broodstock Raceways

Two-year-old and three-year-old Swanson River rainbow trout broodstock cohorts (including two-year-old XX males) and two-year-old and three-year-old arctic char are raised in an outdoor concrete raceway system that contains nine raceways that can be operated in parallel or serial-flow configuration. Rainbow trout are stocked into the outdoor raceways at one year of age. This raceway system was patterned after the coldwater fish hatcheries that were designed by Harry Westers for the Michigan Department of Natural Resources. The broodstock raceway system was built in 1981. Each raceway is 10 ft wide by 100 ft long and is operated with 2.5 ft of water depth, which yields a culture volume of approximately 19,000 gallons. 800–900 gpm of water is used within these raceways, which produces a velocity 2.2–2.5 cm/s. This 2.2–2.5 cm/s water velocity is less than ideal for moving solids out of the raceway and thus these raceways have to be periodically brushed and flushed. Water velocities of at least 4 cm/s are better for solids flushing and traditional trout culture in places such as Idaho and North Carolina typically operate under these higher water velocities. These raceways were originally designed to operate using twice this water flow and thus would have had more appropriate water velocities for solids flushing. Wester's-type baffles were tested before current management was in place in an attempt to improve solids flushing from the raceways. However, indications are that the baffles caused the fish to crowd up at the head of the raceway and were not effective at flushing solids from the raceways.

From March 15 until October 1, the broodstock raceways use water warmed to approximately 10ºC. After October 1, the broodstock raceways use cold water at ambient temperatures of 2–7ºC. The water is heated from March 15 until October 1 in order to induce spawning and increase growth in the rainbow trout reared in these raceways.

Reuse pumps have been installed to return some of the water flow used in the raceways back to the head of the raceways, and this increased water flow will deliver more oxygen to the fish within the raceway and will also increases the velocity of water passing through the raceways.

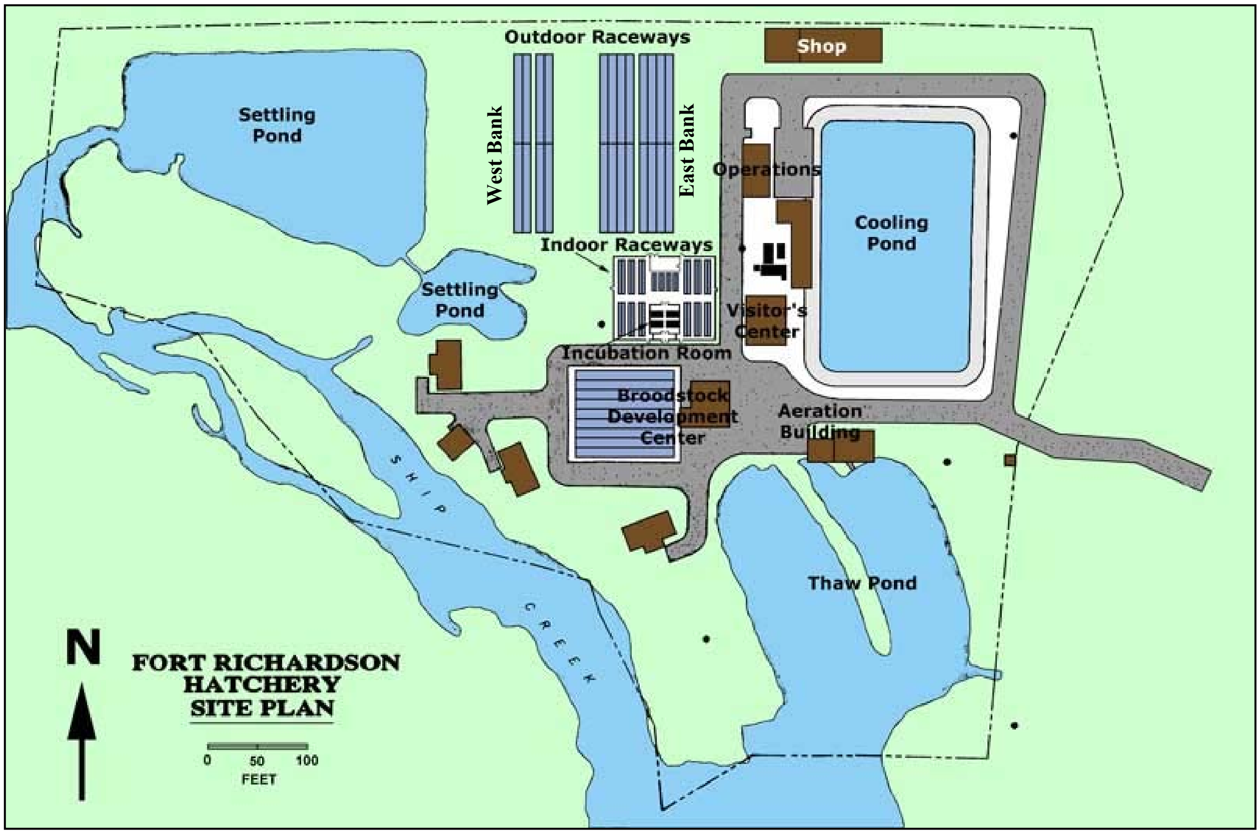

Figure 18. Site plan for Fort Richardson SFH.

Indoor Raceways and Egg Incubation Building

Egg Incubation

Hatching occurs in the incubation room within the indoor raceway building. Approximately 200–300 gpm of water are required for incubation purposes. The incubators are used to hatch rainbow trout eggs from April 15 to July 1. Chinook salmon eggs are incubated from July to October. Coho salmon eggs are incubated from October to February. Approximately 250,000 arctic char eggs are incubated from October until March. Incubation temperatures range from 3.5 to 12ºC.

Indoor Raceways

Fort Richardson SFH has 24 indoor concrete raceways that each contain approximately 1,700 gallons of water (6.4 m^3). The indoor raceways use first-pass heated water nearly all year. The heated water discharged from the indoor raceways is currently flowing by gravity for a second use in the East Bank of outdoor raceways.

The indoor raceways were originally installed with 9 inch diameter oxygen injection columns. According to Jeff Milton, these oxygen injection columns were problematic, especially in changing weather conditions. The fish appeared to be very sensitive to total gas pressure (including sensitivity to low supersaturations of dissolved oxygen), thus they have converted these oxygen columns to vacuum degassing units that are operated with a vacuum pulled by regenerative blowers. Individual blowers draw air from multiple degassing columns. According to Jeff Milton, the occurrence of gas bubble trauma in the indoor raceways was eliminated (or at least significantly reduced) when these 9 inch columns were converted from oxygen injection units into vacuum degassing units.

A mass balance on the oxygen requirements within one of the indoor raceway tanks during a maximum fish feeding event is shown here to point out how much dissolved oxygen concentration must be supplied to meet fish respiration demands and the corresponding dissolved carbon dioxide concentration that would be produced:

- Assuming 18,000 arctic char at 35 g/fish are being fed 1.8% bw/day, then the maximum feed input into that raceway section can be estimated as about 11.3 kg feed/day:

$$\frac{kg\ feed}{day \cdot raceway} = \frac{18{,}000\ fish}{raceway} \cdot \frac{35\,g}{fish} \cdot \frac{1.8\,g\ feed}{100\,g\ fish \cdot day} \cdot \frac{kg}{1000\,g} = 11.3\,kg\,feed\,/\,day\,/\,raceway$$

- Then, if the fish consume 11.3 kg feed per day in a flow of 150 gpm, the fish would require 5.5 mg/L of dissolved oxygen across this raceway unit (assuming steady-state conditions):

$$mg\,/\,L\,DO = \frac{11.3\,kg\ feed}{day} \cdot \frac{0.4\,kg\,DO}{kg\ feed} \cdot \frac{10^6\,mg}{kg} \cdot \frac{min}{150\,gal} \cdot \frac{gal}{3.8\,L} \cdot \frac{day}{1440\,min} = 5.5\,mg\,/\,L\,DO\ consumption$$

This available oxygen requirement is too large to be met without resorting to either in-raceway oxygenation (i.e., micro-bubble diffused oxygenation) or to oxygen supplementation using an oxygen transfer device located at the head of raceway. Micro-bubble diffused oxygen is used at different locations within the raceways to supplement dissolved oxygen levels, which avoids creating a dissolved oxygen supersaturation at the head of the plug-flow raceway. However, the transfer efficiency of micro-bubble diffused oxygen is lower than would be achieved using a dedicated oxygen transfer unit that is located at the head of a given raceway.

East and West Bank Outdoor Raceways

The East and West Bank outdoor concrete raceway systems were built from 1982–1983. These raceway systems were patterned after the coldwater fish hatcheries that were designed by Harry Westers for the Michigan Department of Natural Resources. The raceways have some pitting and cracking (Figure 19) after nearly 20 years of operation in a harsh environment.

The East Bank has four parallel groups of four serial reuse raceways. Each raceway is 8 ft wide by 100 ft long and is operated with 2.5 ft of water depth. The East Bank of outdoor raceways is currently being used to produce approximately 13 g Chinook salmon smolt and approximately 100 g catchable rainbow trout, arctic char, and arctic grayling. These raceways receive about 2,000 gpm of second pass heated water that is coming from the nursery building. Due to the limited water supply, the East Bank of raceways has never been fully utilized and only three of the raceway passes have ever been in operation at one time. As a result, each of the three parallel groups of raceways receives about 700 gpm of water flow. At these flowrates, water moves through each raceway at only 2.4 ft/s. At the end of each of the four raceways passes there are quiescent zones for solids settling with a stand pipe for slurry removal. Fish are harvested using a Magic Valley Heli-Arc fish pump that is placed near the quiescent zone and the fish are crowded towards the pump intake (Figure 20). Pathogen entry into the East Bank of raceways is more likely because the water supply to the raceways is second pass water coming from the nursery building. Therefore, if one group of fish becomes ill in the nursery building, all fish in the East Bank of raceway will be exposed to the pathogen.

The West Bank has two parallel groups of four serial reuse raceways. Each raceway is 8 ft wide by 100 ft long and is operated with 2.5 ft of water depth. The West Bank of outdoor raceways is used to raise approximately 4 g coho salmon fingerling to smolt size (about 23 g). These raceways use the same flows (i.e., approximately 700 gpm per raceway) and flow configurations as the East Bank raceways, but rely on cold ambient water temperatures year round. Coho are moved to the outdoor raceways on June 21 and are harvested from the raceways the following June 15. Previously, the West Bank raceways received pumped third pass water coming from the rainbow trout broodstock raceways. However, to reduce the opportunity for horizontal pathogen transfer, water from the rainbow trout broodstock raceways is no longer serially reused in the West Bank raceways.

Figure 19. The nearly 20-year-old concrete raceways show signs of their age with some pitting and cracking.

Figure 20. A Magic Valley Heli-Arc fish pump with its intake set just in front of the quiescent zone exclusion screen is said to work well harvesting fish from the raceways.

Fort Richardson SFH has always had to operate with less than half of the water flow that it was originally intended to use during normal operation. Water flow is critical because water carries dissolved oxygen to the fish and flushes away the waste metabolites produced by the fish. The reduced water flow through each raceway also reduced the water velocity through each raceway by up to 75%, and this reduced velocity reduces the rate that solids are flushed to the quiescent zone of each raceway.

A mass balance on the oxygen requirements within the East Bank raceways during a maximum fish feeding event is shown here to point out how much dissolved oxygen must be supplied to meet fish respiration demands and the corresponding dissolved carbon dioxide concentration that would be produced:

- Assuming 110,000 chinook salmon at 15 g/fish are being fed 1.5% bw/day, then the maximum feed input into that raceway section can be estimated as about 25 kg feed/day:

$$kg\ feed\ /\ day = \frac{110{,}000\ fish}{raceway} \cdot \frac{15\ g}{fish} \cdot \frac{1.5\ g\ feed}{100\ g\ fish \cdot day} \cdot \frac{kg}{1000\ g} = 25\ kg\ feed\ /\ day\ /\ raceway$$

- Then, if the fish consume about 25 kg feed per day in a flow of 800 gpm, the fish would require about 2.2 mg/L of dissolved oxygen across this raceway unit (assuming steady-state conditions):

$$mg\ /\ L\ DO = \frac{25\ kg\ feed}{day} \cdot \frac{0.4\ kg\ DO}{kg\ feed} \cdot \frac{10^6\ mg}{kg} \cdot \frac{min}{800\ gal} \cdot \frac{gal}{3.8\ L} \cdot \frac{day}{1440\ min} = 2.2\ mg\ /\ L\ DO\ consumption$$

Based upon this oxygen balance, a four-fold reuse would require supplying 8.8 mg/L of available dissolved oxygen to account for fish respiration. This available oxygen requirement is too large to be met without resorting to oxygen supplementation or more than one aeration step. Oxygen transfer devices, like those located at the head of raceway units, have been used widely in North America to meet increased oxygen demands without resorting to increased water flows. However, Fort Richardson SFH has experienced what appears to have been gas bubble trauma at what would typically be considered extremely low levels of total gas pressure supersaturations (about 102%). The hatchery staff has indicated that even dissolved oxygen supersaturation levels of less than 105% have created problems with sensitive fish under the plug flow conditions found in raceways. Published literature does not indicate any salmonid health problems would be created by dissolved oxygen concentrations of only 105% of saturation. However, the experience at Fort Richardson SFH with the native Swanson River strain of rainbow trout contradicts the published literature. For these reasons, relatively inefficient micro-bubble oxygen diffuser are used at different locations within the raceways to supplement dissolved oxygen levels, which avoids creating a dissolved oxygen supersaturation at any given location. The only draw-back to this solution is that the transfer efficiency of micro-bubble oxygen diffusers is lower than would be achieved using a dedicated oxygen transfer unit that is located at the head of a given raceway.

Additionally, an oxygen consumption of 8.8 mg/L would produce approximately 13 mg/L of dissolved carbon dioxide after a four-fold serial reuse. Without aeration to remove dissolved carbon dioxide, adding an additional 13 mg/L of dissolved carbon dioxide to the raceway water might create fish health problems under the conditions (i.e., low alkalinity and soft water) found at Fort Richardson SFH. Note that the conditions just analyzed were assuming the maximum load that could occur at the Fort Richardson SFH. Typical operating levels do not approach this maximum loading.

Both East and West Bank raceways have small 8 inch (20 cm) hydraulic drops at the end of each raceway, immediately after the quiescent zone, and some reaeration occurs as the water plunges into the next raceway (Figure 21). Both East and West Bank raceways have pumps and aeration columns for aeration at the end of the first three raceways in series (Figure 22). These pumps and aeration columns are being removed or have already been removed in the transition to partial reuse (approximately 70% water reuse) of the raceway effluent.

Figure 21. An 8 inch hydraulic drop at the end of each raceway, located immediately after the quiescent zone, provides some reaeration as the water flows to the next raceway.

Figure 22. The East and West Bank raceways will occasionally use pumps (not shown) to lift water through cascade columns that aerate the water at the end of the first three raceways in series.

A mass balance on the oxygen requirements within the West Bank raceways during a maximum fish feeding event follows:

- Assuming that 125,000 coho salmon at 22 g/fish are being fed 0.5% bw/day, then the maximum feed input into that raceway section is:

$$Kg\ feed\ /\ day = \frac{125{,}000\ fish}{raceway} \cdot \frac{22\,g}{fish} \cdot \frac{0.5\,g\ feed}{100\,g\ fish \cdot day} \cdot \frac{kg}{1000\,g} = 14\,kg\,feed\ /\ day\ /\ raceway$$

- Then, if the fish consume 14 kg feed per day in a flow of 800 gpm, the fish would require about 1.3 mg/L of dissolved oxygen across this raceway unit (assuming steady-state conditions):

$$mg\ /\ L\,DO = \frac{14\,kg\ feed}{day} \cdot \frac{0.4\,kg\,DO}{kg\ feed} \cdot \frac{10^6\,mg}{kg} \cdot \frac{min}{800\,gal} \cdot \frac{gal}{3.8\,L} \cdot \frac{day}{1440\,min} = 1.3\,mg\ /\ L\,DO\,consumption$$

Based upon this oxygen balance, a four-fold reuse would require supplying 5.2 mg/L of available dissolved oxygen to account for fish respiration. This available oxygen requirement could be met with supplemental aeration without resorting to oxygen supplementation. Also, dissolved carbon dioxide accumulation should not be a problem at this level of intensification.

Partial Water Reuse System Installations

East Bank Raceways

Water reuse piping and vacuum degassing columns are being added to the East Bank of outdoor raceways so that these raceways can be operated on cold ambient water temperatures year round, similar to the West Bank raceways. This change will reduce the risk of pathogen introduction with the water supply, compared to the existing practice where second pass water is used. After all of the physical changes have been made to allow for internal water reuse, the East Bank of outdoor raceways will be used to produce approximately 13 g chinook salmon smolt. These raceways will be operated with only about 1,000 gpm of the cold (ambient temperature) well water. About 240 gpm of this cold make-up water will be used in each of the four raceway series. One three horsepower pump is being installed at the end of each raceway to return 560 gpm to the head of each raceway for further reuse. Reuse water will be passed through a vacuum degassing/aeration column before entering the raceway.

Fort Richardson SFH is presently retrofitting the East Bank and West Bank raceways with pumps located in the quiescent zones of a given raceway to provide for some partial-reuse of water within individual serial-reuse raceway banks. The goal is to achieve as much as 75% water reuse in a given raceway. Water reuse would increase raceway water flows while reducing make-up water demand supplied to each raceway. The increased flow to each raceway would increase the mass of dissolved oxygen transported to the fish without requiring use of supplemental oxygen (or with much lower oxygen supplementation requirements). Water reuse would also increase water velocities within the raceway, which are only about half of the recommended 4 cm/s. However, implementing water reuse will also allow for waste metabolites such as dissolved carbon dioxide, total ammonia nitrogen, and suspended solids to accumulate to even greater levels if they are not treated during reuse. For example, assuming that no active aeration was provided, then in the worst case scenario the dissolved carbon dioxide concentration could accumulate as high as 34 mg/L after the East Bank raceways have been converted to 70% reuse, i.e.,

- Assuming that 110,000 chinook salmon at 15 g/fish are being fed 1.5% bw/day in each raceway, then the maximum feed input into a group of four raceways can be estimated by the following:

$$kg\ feed\ /\ day = \frac{4\,raceways}{group} \cdot \frac{110{,}000\ fish}{raceway} \cdot \frac{15\,g}{fish} \cdot \frac{1.5\,g\ feed}{100\,g\ fish \cdot day} \cdot \frac{kg}{1000\,g} = 99\,kg\,feed\ /\ day\ /\ group$$

- If the fish consume 99 kg feed per day across a series of four raceways where 70% of the total raceway flow is pumped back to the head of the raceway (e.g., a make-up flow of only 240 gpm with 560 gpm pumped back), the dissolved carbon dioxide concentration would reach about 34 mg/L by the end of the last raceway (assuming steady-state conditions and that no aeration is provided to strip carbon dioxide; also ignoring the equilibrium between dissolved carbon dioxide and the total carbonate system):

$$mg / L\ CO_2 = \frac{99\,kg\ feed}{day} \cdot \frac{0.45\,kg\,CO_2}{kg\ feed} \cdot \frac{10^6\,mg}{kg} \cdot \frac{min}{240\,gal} \cdot \frac{gal}{3.8\,L} \cdot \frac{day}{1440\,min} = 34\,mg / L\ CO_2\ \ production$$

If all reused water is returned to the head of each raceway series without significant aeration to strip some of this dissolved carbon dioxide, then adding an additional approximately 34 mg/L of dissolved carbon dioxide to the raceway water would likely create some fish health problems under the low alkalinity and soft water conditions found at the Fort Richardson SFH. Note that the conditions just analyzed were assuming the maximum loading conditions that may be at Fort Richardson SFH. Typical operating loading levels do not approach this maximum.

Carbon dioxide (CO_2) is a gas that is very soluble in water – over 40 times more soluble than oxygen – and for this reason dissolved carbon dioxide does not significantly elevate total gas pressure nor produce gas bubble trauma (as can dissolved nitrogen, oxygen, and argon). Fish ventilate dissolved carbon dioxide (a by-product of metabolism) through their gills, producing about 0.3 to 0.4 kg of carbon dioxide for every kilogram of feed consumed. Therefore, shifts in dissolved carbon dioxide concentrations can be quite rapid, corresponding to periods of peak oxygen consumption. Elevated and toxic levels of carbon dioxide can occur in intensive fish culture systems using oxygenation to obtain high fish densities if these systems have inadequate water exchange and aeration. Low intensity aquaculture systems do not use oxygenation to support high fish densities, and generally have sufficient aeration and water exchange to keep dissolved carbon dioxide from accumulating to toxic levels.

Dissolved carbon dioxide is in acid-base equilibrium with the total carbonate carbon system, which means that its dissolved concentration is dependent upon the pH and the aqueous concentration of total carbonate carbon present. Adding a base such as sodium hydroxide, sodium bicarbonate, or calcium oxide will produce a pH rise and a shift in equilibrium to reduce concentration of carbon dioxide. Dissolved carbon dioxide can also reach equilibrium with the partial pressure of carbon dioxide in the surrounding atmosphere according to Henry's law. During aeration, if there is enough air-water contact, a significant fraction of the dissolved carbon dioxide can be removed from water and transferred to the air (Colt and Orwicz, 1991). Ventilated cascade columns are often used to strip dissolved carbon dioxide because they can be designed to contact the 5-10 volumes of air required per unit volume of water flow. Therefore, aeration columns and alkaline chemical addition are both viable options for increasing pH and controlling carbon dioxide accumulation in recirculating systems.

Safe levels of dissolved carbon dioxide depend upon fish species, developmental stage of the fish, and other water quality variables that include alkalinity, pH, and dissolved oxygen levels (Wedemeyer, 1996). For example, dissolved carbon dioxide begins to effect salmonids at concentrations > 20 mg/L, but tilapia, hybrid striped bass, sturgeon, catfish and many other warm water species will tolerate considerably higher dissolved carbon dioxide levels in their environment. Even the 20 mg/L recommended safe level for salmonid culture may be conservative if dissolved oxygen concentrations in the water are at or above saturation levels. Sufficiently elevated carbon dioxide levels can decrease the ability of hemoglobin to transport oxygen (the Bohr effect), decrease the maximum oxygen binding capacity of blood (the Root effect), and increase blood acidity (i.e., hypercapnia). As dissolved carbon dioxide concentrations approach 30-40 mg/L, the blood oxygen carrying capacity of salmonids will be depressed to the point where even high environmental dissolved oxygen concentrations may be insufficient to prevent decreased blood oxygen levels. For instance, if carbon dioxide levels are high (e.g., ≥ 30 mg/L for salmonids), then the concentration of dissolved oxygen that is considered safe should be increased by 3-4 mg/L to 11 to 12 mg/L (Colt et al., 1991). Fish may also be able to tolerate higher concentrations of dissolved carbon dioxide when reared in water with high alkalinity, pH, or both, because these conditions strengthen the fish's blood buffering capacity (Wedemeyer, 1996). Yet, to be safe, dissolved carbon dioxide accumulation should be minimized whenever possible.

Clinical signs of a carbon dioxide problem in rainbow trout include: moribund fish, gaping mouths, flared operculums, and extra-bright maraschino-red gill lamella (Noble and Summerfelt, 1996). Sustained exposure to elevated levels of carbon dioxide may also produce nephrocalcinosis (Wedemeyer, 1996), i.e, the formation of calcareous deposits in the kidneys, which cannot be detected from external observations.

(adapted from: Summerfelt, S., Bebak-Williams, J., and Tsukuda, S. 2001. Controlled systems: Water reuse and recirculation. In G. Wedemeyer (Ed.), Fish Hatchery Management. Bethesda, MD: American Fisheries Society.)

Broodstock Raceways

A 30 inch diameter vacuum degassing column (Figure 23) is installed in the broodstock raceways to treat water pumped from the quiescent zones to the head of the raceway to achieve some partial reuse of the water. However, when the reused water is returned to the head of the broodstock raceways through the 30 inch diameter vacuum degassing column, then virtually no aeration occurs to strip some of the dissolved carbon dioxide produced by the fish. Therefore, it is recommended that the reused water be passed through an aeration column designed to ventilate at least 10 volumes of air flow for every 1 volume of water flowing passing through the column.

Figure 23. A 30 inch diameter vacuum degassing unit has been installed in the broodstock raceways to treat water pumped from the quiescent zones to the head of the raceway.

Indoor Raceways

The indoor raceways are also being plumbed for partial-water reuse within each raceway. Water reuse is being implemented by pumping water with one 1.1-hp pump per raceway from each raceway's quiescent zone (Figure 24) to the beginning of that same raceway. The reuse water flow is introduced into the vacuum degassing column (Figure 25) with the make-up water for dissolved gas conditioning. If all reused water is returned to the head of each indoor raceway through the 9 inch diameter vacuum degassing columns, then virtually no aeration has been provided to strip dissolved carbon dioxide from the water.

In all instances of water reuse, levels of dissolved carbon dioxide can accumulate within each culture system if the degassing columns employed do not effectively strip dissolved carbon dioxide. Unfortunately, vacuum degassing units are not well suited for removing dissolved carbon dioxide, because they typically move so little air flow through the water flow. We recommend considering passing the reused water through forced ventilation aeration columns (designed to provide 10 volumes air flow per 1 volume of water flow) to improve carbon dioxide stripping in each reuse system. The existing vacuum degassing columns would be used at the head of each raceway group to degas the make-up water flow, which would be treated separate from the recirculated water flow.

Figure 24. Each indoor raceway is now being plumbed to pump water from its quiescent zone to the beginning of that same raceway in order to achieve up to 75% partial water reuse. This reuse water is mixed with the raceway's make-up water just before it flows into the raceway's vacuum degassing column (see Figure 25).

Figure 25. Each indoor raceway contains a 9 inch diameter vacuum degassing column to treat the water supplied to each raceway and, just recently, to also treat the water flow that is pumped back from the quiescent zone of each raceway to achieve some partial reuse of the water.

Abandoned Wastewater Treatment and Water Recirculation System

In the late 1990's, a large wastewater treatment system was installed at a cost of approximately $4 million to treat the water flow coming out of the Incubation Building, East Bank raceways, West Bank raceways or Broodstock raceways and then return this flow for reuse. The project also included installation of piping to connect to a potable heated water supply that was said to be available on the Fort Richardson Military Reservation. This system was designed so that it could also draw Ship Creek water directly into process stream before attempting to disinfect it.

According to Fort Richardson SFH staff, the wastewater treatment facility was intended to operate as follows:

- Water flow could be directed to the Water Treatment Building from just about any where in the SFH. The water flow exiting the Incubation Building, East Bank raceways, West Bank raceways or broodstock raceways was routed to the wastewater treatment building.
- There are two completely separate flow streams within the treatment building: one for cold ambient water and one for heated water.
- Two parallel sumps were provided to receive either the cold ambient water or the heated water and then direct these flows to two identical but completely separate treatment trains
- Each treatment train consisted of: a microscreen drum filter, pump sump and pumps, and ozone and UV irradiation systems. Alternately, the water flow could be by-passed to the large settling pond.
- In a given treatment train, after flowing through the microscreen drum filters, the water would have flowed into a large sump containing the recirculating pumps and an overflow to the large settling pond.
- The pumps in each treatment train was intended to drive the recirculating water flow through a static mixer for ozone transfer and then continue piping this water flow to a large concrete ozone contact basin where ozone inactivation of micro-organisms could occur.
- Water overflowing the top of the ozone contact basin would have then passed through a vertical UV irradiation channel.
- The treated flow would have then flowed by gravity to the head of the East Bank or West Bank raceways.
- Before the water entered the East Bank or West Bank raceways it would have been passed through a cascade aeration column to reduce any supersaturations of dissolved gasses, especially dissolved oxygen and any residual ozone.

Based only on a quick assessment of this system and viewed simply from a unit process standpoint, the components used within the recirculating system should have been capable of treating water for partial reuse through the East Bank or West Bank raceways (Figure 26). Unfortunately, according to Jeff Milton the wastewater treatment system for recirculation had to be abandoned because of several design details that created operational problems that could not be overcome. The foremost problems appear to have been the lack of cleanouts and low water velocities that were too slow within the pipeline carrying the water discharged from the Incubation Building to the wastewater treatment system and also within the sumps that precede the drum filters. The water velocity was inadequate to prevent solids from settling out in these pipes and flow splitting sumps, nor was the water velocity sufficient to strip the thick fungal/filamentous growth from the pipe and sump walls. Even at maximum flow, indications are that pipelines and sumps could not be flushed to waste and that access for cleaning was almost non-existent. In order to have reduced these problems, meticulous attention to detail is required when selecting the size, slope, and pipe clean-out points for each recirculating systems, because these details not only influence the water transmission, but they also influence how "free" from solids the system can be maintained. All pipes, channels, and stand-pipes should have been sized to produce a water velocity of at least 2–3 ft/sec at the design flow rate when water is flowing by gravity. However, the problem may have been that the piping was never operated at the design flowrate, which theoretically would have created water velocities sufficient to flush the settleable solids and filamentous growth from the pipelines and flow splitting channels. Either way, the pipe runs should have also been designed with clean-out points to allow the pipes to be simply and frequently (daily or weekly) flushed and sometimes brushed to further reduce solids deposits and biofilm mat growth within pipes. It should have been designed so that the water flushed from pipes during clean-out periods could have been discharged outside of the recycle system so that these routine flushing operations do not degrade water quality in the culture tank. Piping should have been installed to carry the cleaning flows away from the recirculating system and to the large settling pond. Cleanout points and bypasses should have also been located to flush deposits of settled solids and thick biofilm growth from:

- the pipeline connecting the East Bank raceways to the wastewater treatment facility,
- the flow splitting sumps before the drum filter,
- the large pump sump, and
- the large ozone contact chamber.

Other problems with flow hydraulics and air entrainment were reported. For these reasons, the wastewater treatment system was deemed inoperable and was abandoned. Water flowing from the East Bank raceways is currently flowing to the wastewater treatment building, but after reaching this building the water is by-passed to the large settling pond.

The second part of this approximately $4 million project was to acquire an additional 2,000 gpm of water by installing a pipeline from the existing potable water delivery system supplying Fort Richardson. This water was expected to arrive at approximately 75ºC and be de-chlorinated before entering the process flow stream. Unfortunately, Jeff Milton indicated that once the hot water supply was turned on they found that the water did not arrive 'hot' or even 'warm' and that only a fraction of the expected flow was truly available. The potable water was also found to be super chlorinated at times leading to insufficient treatment at the chemical injection station which would have resulted in massive fish mortalities. Therefore, this water source was abandoned.

Hatchery Operation and Maintenance Budget

According to hatchery records for fiscal years 2000 and 2001, Fort Richardson SFH has paid $260,000 to $290,000 annually to purchase electric power and well water (i.e., the one well water supply is purchased from the U.S. Army). The majority of the electrical expenses are due to the size and number of pumps and compressors that are in near continuous operation supplying water and oxygen gas to the fish culture systems, e.g.:

- 20–21 pumps may be used to draw water from the well field,
- four groups of relatively large pumps (with 2–3 pumps in each group) move the well water supply and power plant heated effluent through the heat exchange and aeration building (Figure 11),
- many smaller pumps return some of the water for reuse at the fish culture systems, and
- several compressors provide pressurized air for use in the PSA oxygen generation system.

Biological Production Schedule

A balance between fish production needs and water supply constraints has resulted in the current operation of Fort Richardson SFH to meet the following fish production goals (2000 Annual Management Plan, Alaska Department of Fish and Game):

- 2.5 million fingerling (@ 2 grams each), including
  - rainbow trout,
  - coho salmon,
  - lake trout,
  - Arctic grayling, and
  - Arctic char
- 250,000 sub-catchables, including
  - rainbow trout,
  - lake trout,
  - hybrid salmon
  - coho salmon
  - Arctic grayling, and
  - Arctic char
- 300,000 catchables (about 100 g each), including
  - rainbow trout,
  - lake trout,
  - hybrid salmon
  - chinook salmon
  - Arctic grayling, and
  - Arctic char
- 1,000,000 coho salmon smolt (about 20 g each)
- 250,000 chinook salmon smolt (about 15 g each)

The Fort Richardson SFH management plan for fish production maximizes the use of the heated water resource to produce a wide variety of species and size classes (Figure 26).

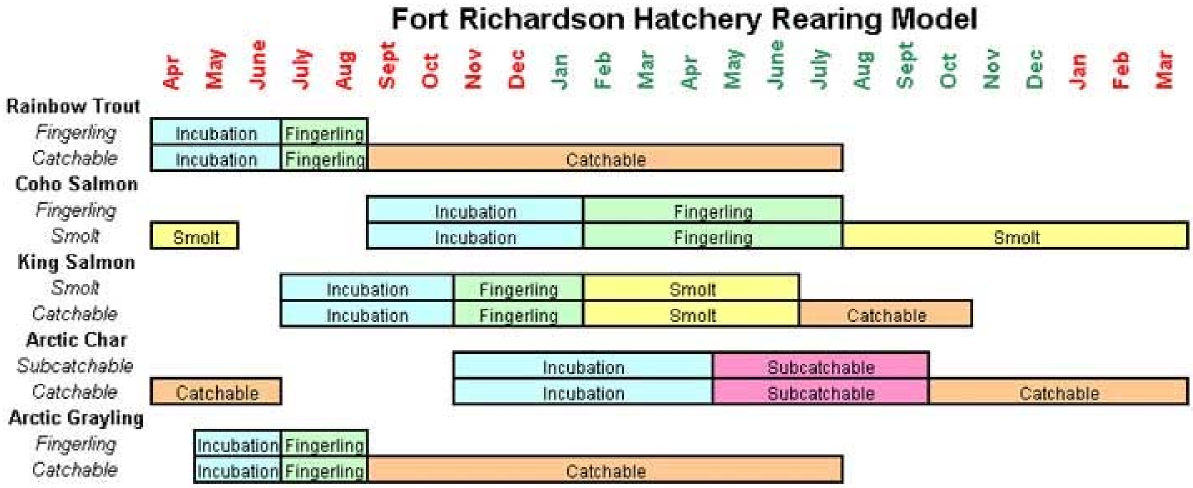

Figure 26. Fish production schedule at the Fort Richardson SFH.

Feed Fed

To meet this wide variety of fish production goals has meant that the SFH relies upon several types of fish feed, including:

- Moore Clark Nutra feed for the rainbow trout, coho and chinook salmon;
- Bio-Oregon moist feeds for the arctic grayling and rainbow trout;
- Moore Clark Pedigree Trout Diet for the rainbow trout broodstock;
- Ewos feeds for the chinook salmon.

Fish Health

Pathogens of Concern

Past History of Disease

The primary fish health concerns are gas bubble disease, fungus sp., and Furunculosis. *Aeromonas salmonicida* is considered ubiquitous to the region. Bacterial kidney disease (BKD) has never been diagnosed at Fort Richardson SFH, but is a concern because it was a problem at Elmendorf SFH in 1986. All high risk salmon stocks are single family tracked to reduce potential BKD exposure.

Minor Infections

Rainbow trout broodstock were recently exposed to Ship Creek water instead of the normal well water supply and have since experienced some fish health problems caused by Gyrodactylus and

Enteric Red Mouth disease. Gyrodactylus does not appear to cause mortality, but is blamed for fin loss. In one instance, rancid feed was considered to have caused a fish health problem.

Biosecurity Protocols

Surveillance of Broodstock

Many of the egg takes are from wildstocks (i.e., arctic char, arctic grayling, coho salmon, and chinook salmon). High risk parental stocks are tested at the single family level for BKD. In the case that a positive is found, the entire incubation tray is destroyed if that tray contains eggs from the single family that tested positive. Eggs are disinfected with iodophors at 100 ppm for 10 minutes at the Fort Richardson SFH.

And, as previously mentioned, parent/donor fish are checked for infectious hematopoietic necrosis virus (IHNV) and *Renibacterium salmoninarum*. However, whenever there is a noticeable change in fish behavior, apparent health or mortality within a rearing unit, moribund fish are collected and sent to the states disease lab in Anchorage for evaluation and culture to identify any pathogens.

It is also recommended that to further reduce the risk that other pathogens will be passed on from broodstock to offspring, broodstock should also be checked for other vertically transmitted bacteria and viruses (e.g., IPNV and possibly *Flavobacterium Psychrophilum*).

All rainbow trout eggs are collected on site from captive broodstock. The first onsite arctic char eggtake took place in the fall of 2001 and it is expected that at least some of the future char eggs will come from captive fish.

Equipment Disinfection

All equipment is disinfected with an iodophor or quaternary ammonia solution prior to initial use in rearing containers. Equipment is also disinfected whenever it is moved from one isolated unit to another. Equipment is not disinfected on a daily basis if it remains with a single rearing unit.

Staff Disinfection

Foot baths using quaternary compounds and/or iodophors are used at the entry to different fish culture areas.

Vector Mitigation and Culture Unit Coverings

The raceways have some wire and nylon netting covering them. The wire covering prevents diving bird predation but not perching bird predation (e.g., magpies). Mink and other predators are also not excluded from the open raceways. Therefore, the open raceways allow for several means of pathogen introduction.

<u>Effluents</u>

Solids Collection

Solids are collected in raceway quiescent zones and are also brushed and flushed weekly from the raceways. These settleable solids are flushed to two primary settling ponds. The two settling ponds are also used to treat the normal raceway discharges before this flow is discharged into Ship Creek and therefore the ponds act as full flow settling basins. However, these basins are somewhat shallow at less than 4 ft deep. Both settling ponds have escaped fish resident in them and active duck populations that help to keep the solids in suspension. Dam boards that are located at the settling pond discharge point into Ship Creek are used to control the water level in the larger settling pond. The dam boards on the larger settling pond have been temporarily removed in the past (before the existing management was in place) to flush the settling pond to Ship Creek. The settling ponds were installed at the time of hatchery construction (1981–1983)

Normal Wastewater Flows

Bulk effluent and quiescent zone cleaning flows from the broodstock raceways are independently directed to the small settling pond which then flows to the larger settling pond.

Bulk effluent and quiescent zone cleaning flows from the West Bank raceways are independently directed to the larger settling pond. Bulk effluent from the East Bank raceways is directed to the abandoned water reuse treatment plant and then to the larger settling pond. The quiescent zone cleaning flows from the East Bank raceways are directed to the larger settling pond.

Disinfection/Treatment Flows

There are no provisions for separate discharge of cleaning flows or flows carrying disinfecting chemicals.

Final Effluent Water Quality

Fort Richardson SFH has only limited effluent water quality records. The two data sets collected on 6/28/99 indicate that total suspended solids (TSS) and pH were 1.0 mg/L and 7.41-7.44 units, respectively. Additional water quality data on the effluent from Fort Richardson SFH are shown in Table 1 (SP #2), but they are relatively old – from an April 1991 sampling event.

Discharge Permit

Alaska general discharge permit no. 9640-DB005 allows effluent discharge from March 13, 1998 to March 1, 2003 unless superceded before that time by state certified USEPA NPDES permit or upon issuance of an amended general permit.

Summary of wastewater permit conditions

Fort Richardson SFH operates under a general waste disposal permit for disposal of wastewater from fish hatcheries. The general permit applies to fish hatcheries that use more than 30,000 pounds of fish feed per year. The SFH is required to collect composite sample monthly of 'normal' effluent flows and of 'cleaning' flows. The SFH must monitor settleable solids, TSS, pH and flow and keep these records on station for DEC review if required. Only intermittent effluent water quality data is available at this time.

The general permit limits TSS discharge concentrations to 5 mg/L and 15 mg/L, respectively, for monthly average or daily maximum (composite samples). The daily maximum settleable solids limit is 0.2 mL/L. The water's pH must range from 6.5 to 8.5. The permit requires that effluent samples are to be collected and analyzed in the months from May to October.

The general permit also contains a clause that would ban flushing the settling pond to the creek and an anti-degradation clause:

- Solids, sludges, filter backwash, or other pollutants removed in the course of treatment or control of wastewaters shall be disposed of in a manner such as to prevent any pollution from such materials entering waters of the state.
- The disposal shall not cause adverse effects on aquatic or terrestrial plant or animal life, their reproduction, or habitat.

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Future Programming

The Fort Richardson Military base is switching to a decentralized natural gas boiler system and will be decommissioning the base power plant in the fall of 2003. This eliminates the heated water supply for the SFH and presents a major obstacle for continued fish production under the current biological production program. The other major problem has been that the SFH has always had to operate on water flows that are only about one-half of the design flow.

Hatchery mission changes

The Fort Richardson SFH's mission is not likely to change accept possibly to shift production to the Elmendorf SFH in case the present production program cannot be maintained when the power plant shuts down. Otherwise, the Fort Richardson SFH will likely continue production of coho salmon, chinook salmon, rainbow trout, arctic char, and arctic grayling.

IDENTIFIED NEEDS AND RECOMMENDATIONS

This report has identified three primary actions that need to be considered in order to allow the Fort Richardson SFH to meet needs identified within the existing conditions section of this report (Table 2). Each of the primary needs include 2–6 recommended options (Table 2). Estimated capital costs for each of these options are listed in Table 2. Each of the needs are expanded upon below.

Need #1. Prepare for loss of Fort Richardson power plant waste heat in September 2003

Description

The Fort Richardson power plant is scheduled to close in September of 2003 as the base transitions away from a centralized heating system and develops a distributed heating system throughout the base to achieve better energy efficiencies. Currently, as much as 3,000 gpm of the Fort Richardson SFH's well water supply is being heated from an ambient temperature of only 2–7ºC to approximately 14ºC using waste heat from the Fort Richardson power plant. Replacing this free heat with a natural gas fired boiler system would require approximately 270 billion BTU/year or approximately $1.35 million/yr (Table 3), which would not be practical. Without the opportunity to heat the well water supply, nearly all of the Fort Richardson SFH's fish production will have to rely on ambient well water temperature. However, Fort Richardson SFH's current production levels cannot be maintained at ambient well water temperatures.

Recommendations

To prepare for the loss of waste heat it is recommended that one of the following combinations of options should be selected: **Options (1) & (2)**; **Options (1) & (3)**; **Option (4)**; or **Option (5)**. Implementation of any of these option combinations would maintain fish production goals. However, when all actions proposed within this report are considered, then **Option (5)** is probably the best choice, with **Options (1) & (3)** the next highest recommended choice.

Table 2. Needs and potential options including the associated capital and operating costs of each option.

Needs and potential options	Estimated operating cost ($)	Estimated capital cost (million $)
Need #1. Prepare for loss of Fort Richardson power plant waste heat in September 2003		
1) Shift production between Fort Richardson and Elmendorf SFHs	$12,000[1]	<$0.1
2) Retrofit Indoor Raceways to partial-reuse and operate a new boiler	$56,000[2]	in progress
3) Install modular and separate recirculating systems at Fort Richardson SFH		
a) two tank-based partial-recirc systems located in the Indoor Raceway Building	$25,000[3]	$0.2 to $0.3
b) one new building with two tank-based recirc systems for trout broodfish production	$50,000[4]	$1.5–$2.5
c) two small recirc systems to be set-up within under-utilized spaces	$11,000[5]	$0.2 to $0.3
d) increased fish health monitoring for fish in partial-reuse and fully-recirculating systems	$10,000–40,000	not applicable
4) Replace the heated water source with heated water piped from the Sullivan power plant	uncertain	$4
5) Build a new SFH	uncertain	$9–$16
Need #2. Prepare for the possible loss of the Fort Richardson dam		
1) Lower the well intakes	uncertain	<$0.1 to $0.2
2) Build a new SFH	uncertain	$9–$16
Need #3. Improve the facilities (e.g., safety, biosecurity, water and oxygen use efficiency, etc.)		
1) Upgrade or replace the water pretreatment building's degassing system, heat exchangers, heated water pumps, and retrofit the head pressure feed system to create much larger and deeper head tanks.	a cost savings	$1–2
2) Finish implementing water reuse modifications on all raceway systems**.**	see Need #1	<$0.1–0.2
3) Improve the oxygenation technology used within/between each raceway**.**	a cost savings	<$0.1
4) Enclose East Bank and West Bank raceways with a 230 ft x 230 ft insulated metal building to increase biosecurity and improve working conditions, worker safety, and reliability of systems when heated water is no longer available**.**	increased cost	$2.5–3.0
5) Install columns to strip carbon dioxide from the reuse flows in the East & West Bank raceways.	a slight increase	<$0.1
6) Place a vacuum degassing unit at every point of make-up water use throughout the SFH.	a slight increase	nearly complete

[1] Approximately $12,000/yr is for the electricity (@ $0.07/kWh) required to operate the partial-recirc pumps in the East and West Bank raceways (assuming operation is 12 months per year).

[2] Approximately $50,000/yr of natural gas would be required to heat the make-up water for the indoor raceways and about $6,000/yr is for electricity (@ $0.07/kWh) to operate the partial-recirc pumps.

[3] Approximately $20,000 of natural gas would be required to heat the make-up water for both tank-based partial-reuse systems if they were operated nine months per year. The sum total electrical requirements are estimated at 13-hp to operate both partial-recirculating systems. Therefore, the total electric costs would be approximately $5,000 annually (assuming $0.07/kWh).

[4] Approximately $30,000 of natural gas would be required to heat the make-up water requirements for nine months per year. The sum total electrical requirements (including motors and UV-irradiation units) are estimated at 40-hp to operate both fully-recirculating systems. Therefore, the total electric costs would be approximately $20,000 for 12 months of operation (assuming $0.07/kWh).

[5] Approximately $6,000 of natural gas would be required to heat the make-up water for both tank-based recirc systems if they were operated nine months per year. The sum total electrical requirements are estimated at 8.5-hp to operate both partial-recirculating systems. Therefore, the total electric costs would be approximately $5,000 annually (assuming $0.07/kWh).

Table 3. Energy and cost analysis for replacing the waste heat that is currently provided by the Fort Richardson power plant. Calculations do not assume depreciation of any capital costs for a new a natural gas fired boiler system, but do assume 85% heat transfer efficiency from the boiler to the process water and \$0.50 per 100,000 BTU.

Month	Total flow (gpm)	Culture temp. (°C)	Ambient temp. (°C)	Heat required (BTU/month)	Cost of power (\$1000/month)
Jan	3000	14	0.5	33×10^9	165
Feb	3000	14	0.5	33×10^9	165
Mar	3000	14	3	27×10^9	134
Apr	3000	14	4	24×10^9	122
May	3000	14	7	17×10^9	86
June	3000	14	9	12×10^9	61
July	3000	14	10	10×10^9	49
Aug	3000	14	10	10×10^9	49
Sep	3000	14	9	12×10^9	61
Oct	3000	14	3	27×10^9	134
Nov	3000	14	1	32×10^9	159
Dec	3000	14	0.5	33×10^9	165
Total/yr				270×10^9	\$1,350

Option (1) Shift some production from Fort Richardson SFH to Elmendorf SFH and develop a fish production plan for Fort Richardson SFH that requires little heated water and best utilizes the available cold ambient water supply.

In 2003, to address the loss of the waste heat supply it has been suggested that all anadromous fish and sub-catchable production be shifted to Fort Richardson SFH while all catchable fish production is shifted to Elmendorf SFH. It is recommended that the Fort Richardson and Elmendorf Hatcheries shift fish production as described in Table 4.

The following changes would have to be implemented (as well as some of the changes suggested in **Option (3)**) to shift all anadromous fish and sub-catchable fish production to Fort Richardson SFH while all catchable fish production was shifted to Elmendorf SFH.

- Water reuse piping (including a 3-hp pump on each series of four raceways) and vacuum degassing columns are being added to the East Bank raceways so that these raceways can be operated on cold ambient water temperatures year round, similar to the West Bank raceways. This change will lessen the risk of pathogen introduction with the water supply, compared to the existing practice where second pass water is used. After all of the physical changes have been made to allow for internal water reuse, the East Bank of outdoor raceways will be used to produce approximately 13 g chinook salmon smolt. These raceways will be operated with only 1,000 gpm of the fresh cold ambient temperature well water. About 240 gpm of this cold make-up water will be used in each of the four raceway series. Pumps at the end of each raceway are being installed to return 560 gpm to the head of each raceway for further reuse.

Current plans are to pass the reuse water through vacuum degasser/aeration columns before it enters the head of the raceway. However, ventilated cascade columns would be better suited than vacuum degassing columns to control carbon dioxide in the recirculated water flow (as mentioned before).

- Coho salmon fingerlings would still be raised from approximately 4 g to smolt size (approximately 23 g) on cold ambient water temperatures in the West Bank raceways. These raceways are being converted to partial-reuse as the East Bank raceways.

- Coho salmon, chinook salmon and rainbow trout fry production (to approximately 4 g) would continue in the Indoor raceway building according to either **Option (2)** or **Option (3)** of **Need #1**.

Option (2) Retrofit the Indoor raceways to partial-reuse systems and install a new natural gas fired boiler to heat only the make-up water flow requirements to meet fry production goals.

Some of the indoor raceways are presently being converted from single-pass systems to separate partial-reuse systems so that the requirements for heated water in the indoor raceways would be reduced by about 65%, compared to existing heated water requirements. Retrofitting twenty-four of these indoor raceways to partial-reuse would allow for all fingerling production goals to be met using 64% less water, because each raceway would pump 90 gpm of water (using a 1.1-hp pump) back to the head of the raceway while 35 gpm of first-pass heated make-up water would be added to each raceway. This option would still require approximately 770 gpm of heated water from February to June (for coho salmon fry), approximately 455 gpm of heated water for July and August (for ponded rainbow trout), and approximately 490 gpm for three weeks in December (for first feeding Chinook salmon) (Table 5a and 5b). After the loss of the waste heat from the Fort Richardson power plant, a new boiler would have to be installed to heat the ambient temperature make-up water to at least 10°C (Tables 5a and 5b). A monthly breakdown of the energy requirements for this proposed boiler is shown in Tables 5a and 5b. The heated water required to operate the Indoor raceways on partial-reuse would cost approximately \$50,000/yr to produce (Tables 5a and 5b), assuming an 85% heat transfer efficiency and a \$0.50 cost per therm of natural gas supplied heat. This heated water would be produced with a new natural gas-fired boiler system installed at the well water treatment building, which is proposed below in **Option (1)** of **Need #3**. The annual pumping cost for partial-reuse on the raceways during these periods would be approximately \$12,000/yr (assuming \$0.07/kwh). The indoor raceways currently gravity discharge their heated water to the East Bank of outdoor raceways for a second pass use. In the future, however, the Indoor raceway discharge will be sent to the large settling pond, because biosecurity is severely compromised if this water is used in a second pass through the East Bank of raceways.

Table 4. Shift in fish production proposed for Fort Richardson and Elmendorf hatcheries in order to accommodate the closing of the Fort Richardson power plant in September of 2003.

Species and life stage	**Present Location**	**Proposed New Location**
Rainbow Trout Broodstock	Broodstock Raceways @ Fort Rich SFH	New Recirc Building @ Fort Richardson SFH
Chinook Salmon Smolts	Raceways @ Fort Richardson SFH	Broodstock Raceways @ Fort Richardson SFH
Rainbow Trout Catchables	Raceways @ both hatcheries	Raceways @ Elmendorf SFH only
Chinook Salmon Catchables	Raceways @ Fort Richardson SFH	Raceways @ Elmendorf SFH
Arctic Char Catchables	Raceways @ Fort Richardson SFH	Raceways @ Elmendorf SFH
Arctic Grayling Catchables	Raceways @ Fort Richardson SFH	Raceways @ Elmendorf SFH
Coho Salmon Smolts	Raceways @ Fort Richardson SFH	No change
Coho, chinook, and rainbow trout fry production (to 4 g)	Indoor raceways @ Fort Rich SFH (except for some Chinook salmon at Elmendorf SFH)	Remain @ Fort Rich SFH in new or retrofitted systems in the Indoor Raceway Building

Table 5a. Fish production, water temperature requirements, and heating requirements for the indoor raceways after conversion of each raceway to partial-reuse. These calculations do not assume depreciation of capital costs for a new a natural gas fired boiler system, but do assume 85% heat transfer efficiency from the boiler to the process water and $0.50 per 100,000 BTU.

Month	Species	Raceways (#)	Flow per raceway (gpm)	Culture temp. (°C)	Ambient temp. (°C)	Heat required (BTU/month)	Cost of power ($1000/month)
Dec	chinook	14	35	10*	0.5	3.8×10^9	19
Jan	chinook	14	35	ambient	0.5	0	0
Feb	chinook	14	35	ambient	0.5	0	0
Mar	chinook	14	35	ambient	3	0	0
Apr	chinook	14	35	ambient	4	0	0
May	chinook	14	35	ambient	7	0	0
June	chinook	14	35	ambient	9	0	0
July	rainbow trout	13	35	10	10	0	0
Aug	rainbow trout	13	35	10	10	0	0
Sep					9	0	0
Oct					3	0	0
Nov					1	0	0
Total/yr						3.8×10^9	$19

*assuming only three weeks of heated water will be necessary

Table 5b. Fish production, water temperature requirements, and heating requirements for indoor raceways after all raceways have been converted to partial-reuse. These calculations do not assume depreciation of capital costs for a new a natural gas fired boiler system, but they do assume 85% heat transfer efficiency from the boiler to the process water and $0.50 per 100,000 BTU.

Month	Species	Raceways (#)	Flow per raceway (gpm)	Culture temp. (°C)	Ambient temp. (°C)	Heat required (BTU/month)	Cost of power ($1000/month)
Dec					0.5	0	0
Jan					0.5	0	0
Feb	coho	8	35	10	0.5	2.2×10^9	11
Mar	coho	8	35	10	3	1.6×10^9	8
Apr	coho	8	35	10	4	1.4×10^9	7
May	coho	8	35	10	7	0.7×10^9	3
June	coho	8	35	10	9	0.2×10^9	1
July					10	0	0
Aug					10	0	0
Sep					9	0	0
Oct					3	0	0
Nov					1	0	0
Total/yr						6.0×10^9	$30

Option (3) Install modular and separate recirculating systems at Fort Richardson SFH as needed to meet production goals without heated water from the power plant and with less reliance on Elmendorf SFH.

It is proposed that the Fort Richardson SFH construct three recirculating installation in order to (1) replace one-half of the Indoor raceways and (2) replace the rainbow trout broodstock development raceways. Also, two small demonstration systems could be installed to increase flexibility of production while taking advantage of available space.

Replace one-half of the Indoor raceways with two partial-reuse systems

As an alternate to **Need #1, Option (2)**, it is proposed that the Fort Richardson SFH shift production of rainbow trout, chinook salmon, and coho salmon fry -- at least for the portion of the production cycle that requires heated water -- from Indoor raceways into two new circular tank-based recirculating systems. These two circular tank-based partial-reuse systems could maintain the warmer water requirements necessary to meet production goals defined in Tables 5a and 5b with a minimum heat requirement. These two recirculating systems could be located in the space now occupied by twelve of the indoor raceways, which would provide an area 33 ft x 26.5 ft for each system. Each partial-reuse system would consist of four 12 ft diameter x 3.5 ft deep circular tanks that would incorporate 'Cornell-type' sidewall drains, a drum filter, a pump sump and pumps, and a stripping column stacked over a low head oxygenator (LHO) located at each tank. This partial-reuse system incorporates 'Cornell-type' dual-drain circular culture tanks, which provide uniformly healthy water quality, optimized water velocities for fish health and condition, and excellent solids removal capability. The circular fish culture tanks are operated as swirl separators, concentrating solids and removing them from the culture tank with a relatively small flow from the bottom-drawing center drain. In a 'Cornell-type' dual-drain culture tank, the majority of the flow (relatively free of settleable solids) is discharged from the tank through a fish-excluding port located partway up the tank sidewall. This flow is treated using a rotating microscreen filter and is then pumped to cascade through an aeration column followed by a low head oxygenation unit before the water flows back to the culture tank. The small, concentrated waste discharge from the center drains can also be treated very economically and efficiently with the existing settling ponds. The partial-reuse systems would rely on make-up water flow to maintain un-ionized ammonia levels below toxic levels. This is accomplished by maintaining the system pH at the lowest safe level, by controlling the carbon dioxide concentration at the maximum safe level with the degassing system. Each system would recirculate 500 gpm and would require 55 gpm of heated make-up water, i.e., about a 10% make-up flowrate. The two recirculating systems could maintain the warmer water requirements necessary to meet production goals with less heat demand than the partial-reuse raceways (described in **Option (2)**), i.e., approximately $20,000 of natural gas would be required if both tank-based partial-reuse systems were operated nine months per year. The sum total electrical motor requirements are estimated at 13-hp to operate both partial-recirculating systems, so total electric costs would be approximately $6,000 annually (assuming $0.07/kWh). The remaining twelve indoor raceways would be used without a heated water supply.

Replace the rainbow trout broodstock development raceways with two recirculating systems

It is also proposed that the Fort Richardson SFH shift the rainbow trout broodstock program from the outdoor raceway system into two new, building-enclosed, circular tank-based recirculating systems that could maintain the warmer water requirements necessary to meet production goals with the minimum amount of heat demand (Figure 28). The rainbow trout broodstock require water heated to about 10ºC from March 15 until October 1 in order to induce spawning and increase their growth rate. After October 1, the rainbow trout broodstock are cultured using cold water at ambient temperatures (3–6ºC). This production plan could be accomplished by building two large recirculating systems to provide 10–14°C water and would allow shifting makeup water flows to other systems that would function better if more cold water flow were available, e.g., the East and West Bank raceways. Each fully-recirculating system would consist of five 20 ft diameter x 5 ft deep (4 ft water depth) circular tanks that would incorporate 'Cornell-type' sidewall drains, a drum filter, a pump sump and pumps, a fluidized-sand biofilter, a stripping column stacked over a low head oxygenator (LHO), a UV-irradiation unit and an ozonation unit (Figure 28). Each system would recirculate 1,500 gpm and would require about 75 gpm of heated make-up water (approximately 5% of total flow). The two recirculating systems could maintain the warmer water requirements for nine months per year with approximately $30,000 worth of natural gas. The sum total electrical requirements (including UV-irradiation units) are estimated at 40-hp to operate both fully-recirculating systems, so total electric costs would be approximately $20,000 for 12 months of operation (assuming $0.07/kWh). These two fully-recirculating systems would also serve as the first full-scale demonstration of recirculating technology for fish production at the Alaska Fish and Game and their performance could be assessed before more money and resources are committed to this technology. This building could be located on the 60 ft by 200 ft area that is available between the settling pond and the West Bank raceways.

Install two small recirculating systems to increase flexibility

Fort Richardson SFH could also gain some increased flexibility and further enhance production potential by installing two relatively small recirculating systems in an under-utilized space in the broodstock development center and within the indoor raceway building:

(a) A partial-reuse system with two 12 ft diameter circular culture tanks (approximately 2,500 gallon per tank) could be set-up in the broodstock development center to culture any of the fish required, but arctic char might be the best candidate for culture in this system.

    This partial-reuse system would be designed to recirculate 200 gpm of water using a make-up flow with only approximately 20 gpm of heated make-up water (e.g., 10% of the total tank flow). The bottom drain discharged from each culture tank would be discharged directly to piping running to the larger settling pond. The sidewall flow would be sieved through a microscreen drum filter and then it would be pumped through a cascade aeration column followed by a low head oxygenation unit. No ozone would be required and UV-irradiation would only be necessary if fish pathogen concerns were found to be critical. Approximately $4,000 worth of natural gas would be required to heat the make-up water for this tank-based partial-reuse system if it were operated nine months per year. The sum total electrical motor requirements are estimated at 3.5-hp to operate this partial-recirculating system, so total electric costs would be approximately \$2,000 annually (assuming \$0.07/kWh).

(b) A fully-recirculating system with one 20 ft diameter circular tank (8,000 gallon) could be set-up in the center of the indoor raceway building.

This fully-recirculating system would be designed to recirculate 270 gpm of water using a make-up flow of only 5–20 gpm of heated well water. The bottom drain discharged from each culture tank would be discharged directly to piping running to the larger settling pond. The sidewall flow would be sieved through a microscreen drum filter and then it would be pumped through a fluidized-sand biofilter. The water would then flow by gravity from the top of the fluidized-sand biofilter through a cascade aeration column, then pass through a low head oxygenation unit and finally through a UV-irradiation unit before being returned to the culture tank. An ozonated oxygen feed gas would be transferred to the water flowing through the low head oxygenator. Approximately \$2,000 worth of natural gas would be required to heat the make-up water (assuming 10 gpm) for this tank-based partial-reuse system if it were operated nine months per year. The sum total electrical motor requirements are estimated at 5-hp to operate this partial-recirculating system, so total electric costs would be approximately \$3,000 annually (assuming \$0.07/kWh).

Increase fish health monitoring within the recirculating systems

As the facility increases the degree of water reuse, whether partial-reuse about raceways or circular tanks, pathogens will become more concentrated, as will compounds excreted by the fish. Fish in the system will be at greater risk for production related diseases (i.e., those occurring in intensive culture) such as bacterial gill disease, coldwater disease, columnaris disease and protozoal infestations. These diseases are associated with pathogens that are naturally occurring in soil and water and stocking the system with specific-pathogen-free fish is not likely to decrease the risk that fish will experience an outbreak. Except for the effects of carbon dioxide (e.g., acidosis, nephrocalcinosis), unionized ammonia and nitrite, very little is known about the effect of other fish excretory products such as creatine/creatinine, urea and amino acids. These compounds could have as yet undetermined effects on gill condition and fish physiology. Intensifying culture conditions will also increase stress as fish have to cope with changes in water quality, increased fish density and other changes in the physical environment such as increased noise and vibration.

A monitoring program will help determine how fish are responding to the intensification of water use. Moribund fish should be necropsied and histopathology of gills should be done. Depending on the budget availability, organs such as kidney, liver and spleen should be included. These moribund fish should be assayed for bacteria, viruses and parasites. Periodically, "normal" fish should be examined to determine gill condition. For these "normal" fish, histopathology would be very useful for tracking changes in the population over time, especially if the results are quantified. Depending on the level of interest, blood work could also be carried out in "normal" fish over time to examine stress hormones, complete blood counts (CBCs) and serum chemistries. Cost of implementing this monitoring program is estimated at $10,000 to $40,000 annually, depending upon whether a serious fish health problem develops.

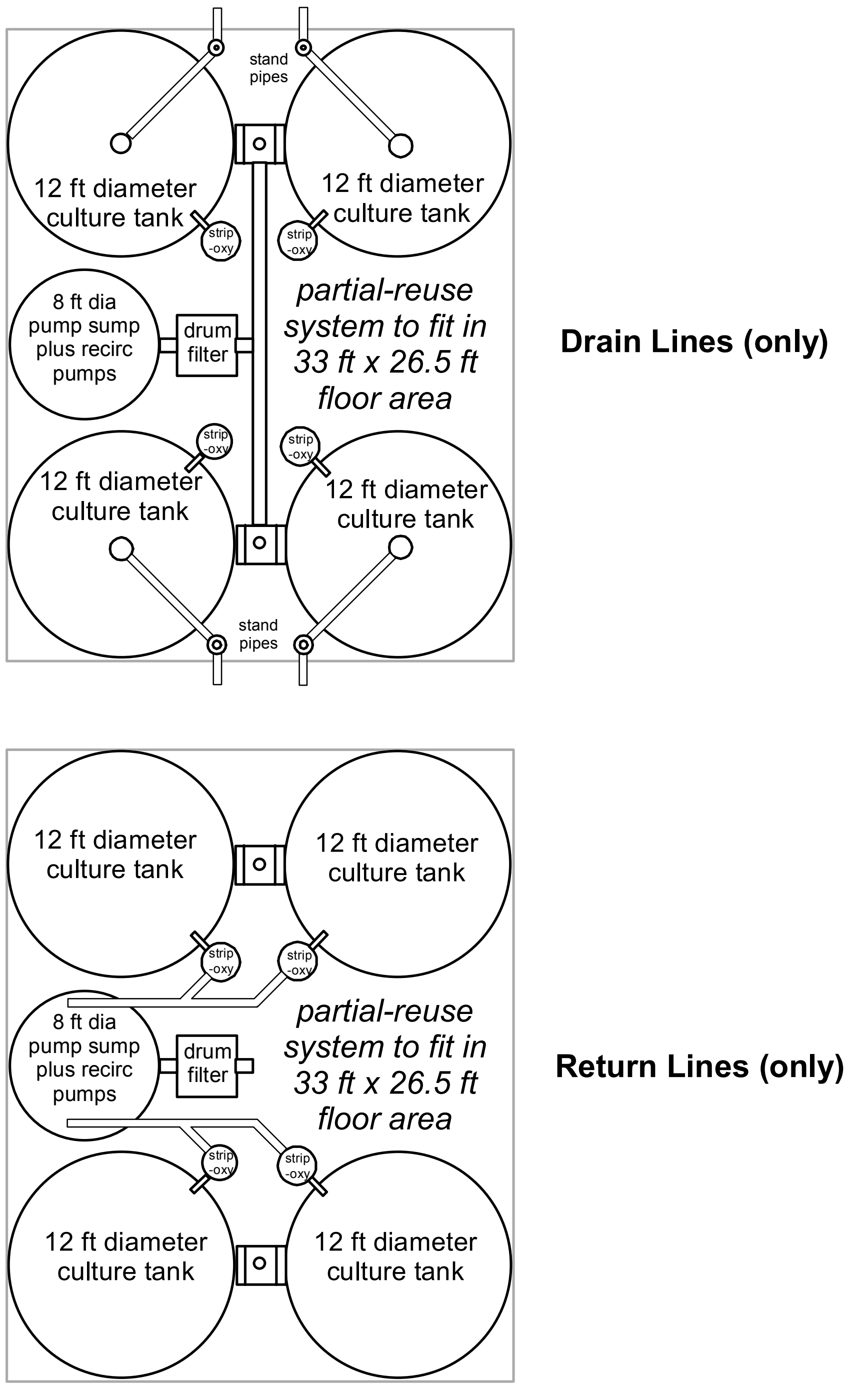

Figure 27. Two partial-reuse systems could be installed where twelve of the indoor raceways are now located. Each system would recirculate 500 gpm of water and would require 55 gpm of heated make-up water, i.e., about a 10% make-up flowrate.

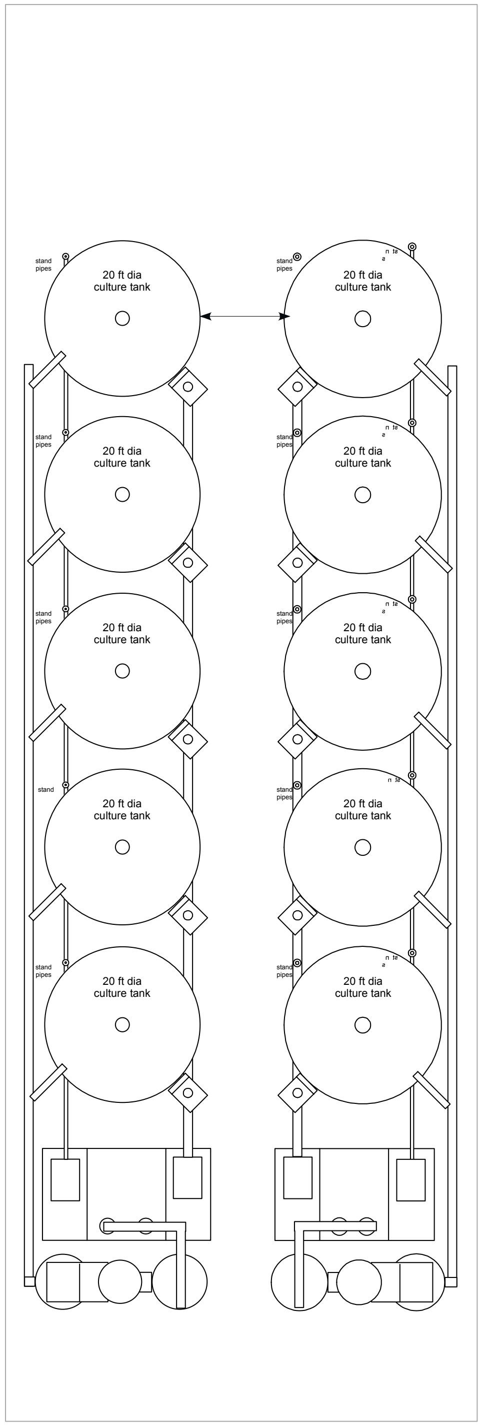

Figure 28. Two recirculating systems have been proposed to maintain the rainbow trout broodstock at 10–14°C water temperatures for at least 9 months per year. Each system would recirculate 1,500 gpm and would require about 75 gpm of heated make-up water (approximately 5% of total flow). Both systems would be installed within a new 60 ft by 200 ft metal building.

Option (4) Replace the power plant heated water source with heated water from the M. L. and P. Sullivan power plant**.**

Waste heat produced at the M. L. and P. Sullivan power plant could be used as a heat source for Fort Richardson SFH. However, two obstacles must be overcome to access this water. First, a well water supply and heat transfer system must be developed at the Sullivan site so that the power plant's waste heat can be transferred to this water supply. Then, a pipeline must be constructed so that this heated water can be transport the approximately 1.5 mile distance to Fort Richardson SFH. The pipeline might have to be insulated to reduce heat loss over that distance. The Alaska Department of Fish and Game has estimated that this project might be completed for $4 million.

Option (5) Abandon Fort Richardson SFH and build a new state-of-the-art fish hatchery.

There is a considerable amount of work that has been proposed in this report to install heated recirculating systems and also to improve the safety, biosecurity, water and oxygen use efficiency, waste capture efficiency, and reliability of the Fort Richardson SFH. For this reason, serious consideration should be given to the option of replacing this hatchery with another new facility that would be built at another location, ideally located in the vicinity where a majority of fish are stocked. A new location would have to have a reliable source of inexpensive heat or natural gas, a minimum of 1,000 gpm of clean groundwater, 3-phase power, and/or should be near key inland stocking waters. Replacing the production supplied by Fort Richardson SFH would require installing new building-enclosed (at $100 per square foot) fully-recirculating systems for each of the following fish production programs:

- Egg incubation
- Fry production
- Rainbow trout broodstock development (as described in **Need #1, Option (3)**), and
- Coho and chinook salmon smolt and catchable production

Table 6. Culture system buildings that have been proposed if the Fort Richardson SFH were to be replaced with a new SFH.

Building	Foot Print (L x W)	Culture tank no. & size (dia x depth)	Tot. culture volume (gallons)	Tot. recirc. flow rate (gpm)	Recirc systems (#)	Type of recirc systems	Capital cost estimate, $\$10^6$
Egg incubation	24' x 50'	Jars and 8-stack incubat.	na	200	4	Heat pump, fully-recirc	$0.4–0.8
Fry production	75' x 150'	Twenty 12'ϕ x 3.5'	50,000	2,500	5	Fully-recirc w/ O_3 & UV	$1.5–2.0
RBT broodstock	60' x 200'	Ten 20'ϕ x 5'	94,000	3,000	2	Fully-recirc w/ O_3 & UV	$2.0–2.5
Coho & chinook	120' x 200'	Twenty 20'ϕ x 5'	190,000	6,000	4	Fully-recirc w/ O_3 & UV	$3.0–4.0

A new hatchery would also likely incorporate a staff office and laboratory building, maybe two on-site residences, and possibly a visitor outreach and education center. Estimates of the cost of these additional facilities:

- The staff office, laboratory and support facilities would locate in a 35 ft x 90 ft metal building that would cost about $300,000–$350,000 (at $100 per square foot);
- Two on-site residences would cost approximately $250,000–$400,000; and
- A visitor outreach and education center that could cost anywhere from $0.2–$2.0 million, depending upon its design.

A new fish hatchery would be designed to provide separate production systems for each species and life stage, except for during egg incubation and then four recirculating systems have been specified. For example, five separate recirculating systems would be required to first feed the fry and rear them to approximately 4 g; one system for each species, e.g., arctic char, arctic grayling, rainbow trout, coho salmon, and chinook salmon.

A new fish hatchery would also require $0.5–1.5 million for water supply development and pretreatment/heating, as well another $0.5–1.0 million for effluent collection, treatment, and routing to discharge. Total cost for this new hatchery would probably range from $9–16 million.

Need #2. Prepare for the possible loss of the Fort Richardson dam

Description

Although the Elmendorf Dam prevents nearly all fish from migrating up Ship Creek, the Fort Richardson dam is still a barrier to natural fish passage on Ship Creek that the Anchorage Waterways Council will eventually want to remove. Therefore, the Anchorage Waterways Council will likely want to see the Fort Richardson dam removed some time after the Fort Richardson power plant has closed in September of 2003. Without the dam, there is a chance that the peziometric pressure may drop on the shallow wells supplying the Fort Richardson SFH, which could reduce the amount of water that they supply to the hatchery.

Recommendations

In the event that dam removal lowers local ground water peziometric pressures, it is recommended that the Alaska Department of Fish and Game consider selecting one of the following options in order to maintain fish production goals if the Fort Richardson dam is removed.

Option (1) Lower the well intakes to allow for continued well operation in the event that dam removal causes local ground water levels to drop**.**

Pricing and feasibility of this option should be investigated with a local well drilling company. However, Option (1) is the preferred choice if ground water levels drop after the dam has been removed.

Option (2) Build a new SFH (abandoning the existing SFH or shifting the focus at the existing site)**.**

See **Need #1, Option (5)** above.

Need #3. Improve the existing facilities

Description

Operating the outdoor raceways exposes workers to conditions that pose dangers from snow and ice, water temperatures of only 2–4ºC, and air temperatures that reach below -20ºC. Operating the outdoor raceways also exposes the fish to several possible biosecurity risks from birds and small mammals that enter the raceways.

Renovations currently underway in the East Bank, West Bank, and Indoor raceways will rely upon diffused oxygen systems to supplement dissolved oxygen concentrations when necessary. Diffused oxygen produces less efficient oxygenation than when transfer units such as Mazzei injectors, low head oxygenators, or oxygen cones are properly used. Incorporating side-stream oxygenation units would be more difficult to implement without a building to cover the pipes used to connect these unit processes to the raceways.

Implementation of partial-water reuse in the East and West Bank Raceways will require installation of cascade aeration columns for stripping dissolved carbon dioxide before the water is returned to the head of each group of raceways.

Improved waste capture may be required in the foreseeable future if more stringent effluent limits are imposed. This is a real possibility. The hatchery would be able to increase waste capture if the several tank-based recirculating system described in **Need #1, Option (3)** were implemented. A new SFH based entirely on tank-based recirculating systems would produce the best overall waste capture (described in **Need #1, Option (5)).**

Recommendations

If the Fort Richardson SFH is to remain open, it is recommended that the Alaska Department of Fish and Game consider implementing all of the following options in order to maintain fish production goals at the Fort Richardson SFH:

Option (1) Upgrade or replace the water pretreatment building's degassing system, heat exchangers, heated water pumps, and retrofit the head pressure feed system to create much larger and deeper head tanks.

Ideally, implementing this option would allow one pumping step at the pretreatment building to be eliminated while providing deeper water head tanks with more water storage capacity to meet short-term demands**.** Additionally, a new natural gas fired boiler and smaller heated water supply pumps would have to be installed to meet the heated water requirements. However, the hatcheries heated water requirements would be significantly reduced if **Need #1, Options (1) and (3)** had already been implemented. It is estimated that this option would cost $1–2 million.

Option (2) Implement water reuse modifications on all raceway systems**.**

Fort Richardson SFH staff are presently converting the East Bank and West Bank raceways to partial-reuse systems that pump water from the last quiescent zone of each four-raceway group to the head of each four-raceway-group. It is recommended that these pumped reuse flows will be passed through a forced ventilation aeration column (designed to provide 10 volumes air flow per 1 volume of water flow) to improve carbon dioxide stripping in each reuse system. The vacuum degassing columns would still be used at the head of each raceway group to degas the make-up water flow, which would be treated separate from the recirculated water flow. Vacuum degassing units are well suited for degassing dissolved nitrogen, but are not well suited for removing dissolved carbon dioxide (because they move so little air flow through the water flow).

Option (3) Improve the oxygenation technology used within/between each raceway**.**

Renovations currently underway in the East Bank, West Bank, and Indoor raceways will rely upon diffused oxygen systems to supplement dissolved oxygen concentrations when necessary. Diffused oxygen produces less efficient oxygenation than when transfer units such as Mazzei injectors, low head oxygenators, or oxygen cones are properly used. Incorporating side-stream oxygenation units would be more difficult to implement without a building to cover the pipes used to connect these unit processes to the raceways. Providing a distributed oxygen flow to be mixed at multiple points within each raceway has been estimated to cost <$100,000.

Option (4) Enclose raceways to increase biosecurity and improve working conditions, worker safety, and reliability of systems when heated water is no longer available.

It is strongly recommended that the Alaska Department of Fish and Game enclose the outdoor raceways to increase biosecurity and improve working conditions, worker safety, and reliability of systems when heated water is no longer available. An insulated metal building large enough to cover both the East Bank and West Bank raceways would be approximately 230 ft by 230 ft. Assuming a cost of $50 per square foot of building, this building would cost approximately $2.5–3.0 million. Costs would include electricity, lighting, and basic HVAC. It would also require electricity to light and natural gas for heating.

Option (5) Install columns to strip dissolved carbon dioxide from the reuse flows in the East and West Bank raceways.

Stripping dissolved carbon dioxide requires contacting large volumes of air for every volume of water treated, generally 5 to 10 air flow volumes for every 1 water flow volume, that is, gas-to-liquid ratios (G:L) of 5:1–10:1. These G:L are several hundred times larger than the ratios of oxygen gas flow volume to water flow volume used in oxygen transfer units (i.e., G:L of 0.005:1–0.03:1).

Cascade columns are frequently used to degas dissolved carbon dioxide from water reuse systems because they incorporate relatively inexpensive and low power ventilation fans to move large volumes of air counter-current to the water flowing through the column. Cascade columns are generally limited to 4 to 6 ft tall, because only diminishing improvements in dissolved carbon dioxide stripping are achieved at greater depths and there are practical limitations on the use of taller columns. The cross-sectional area of these cascade columns is determined based on a hydraulic loading rate of 30–45 gpm/ft^2.

Operationally, carbon dioxide degassing column design requires uniform water distribution across the top of the column. Water distribution can be effective with relatively low-pressure loss, using either spray nozzles, orifice plates, or rotating distributor arms. Carbon dioxide degassing can also be improved by breaking up the water cascade with a plastic media or with stacked screens. However, to avoid fouling problems, a stripping column containing splash screens rather than packing will be easier to maintain when some biological solids production is expected.

It is recommended that a 4 ft diameter cascade column be installed at the head of each raceway group in the East Bank raceways and West Bank raceways. Each of these cascade columns will be used to degas dissolved carbon dioxide from the 550 gpm of water that will be pumped from the quiescent zone of the last raceway within each group of raceways. This column will not be used to treat the make-up flow. Columns can be fabricated from marine grade aluminum sheet or from stainless steel sheet. Each column should be 8 ft tall, with the bottom 1.5 ft of each column submerged in water at the head of each raceway group. Water should be distributed inside each column at the top of each column using either two rotary spray nozzles (as supplied by Tower Tech Inc., Oklahoma City, Oklahoma) or using a distributor mechanism similar to the mechanisms used in the vacuum degassing columns recently installed at Elmendorf SFH. An axial flow fan or squirrel-cage air-handling fan capable of moving 750 cfm (against 1 inch of water pressure) should be supplied with each column so that air can be introduced towards the base of the column — at a location that would place the air entry approximately 12 inches above the water surface. Air should be vented through a domed-lid that flanges to the top of each column. Thus, air will blow upwards through each column in a direction counter-current to the cascading water. The domed-lid should contain random packed plastic media to demist the air vented out the top of the column. Two splash screens, consisting of expanded aluminum sheet (approximately 1 inch by ½ inch openings), should be placed in each column perpendicular to the water flow: one splash screen would be located 6 inch below the water distribution mechanism and the other splash screen would be located 4 ft below the top of the column.

Option (6) Place a vacuum degassing unit at every point of water use throughout the SFH.

This option will be completed by hatchery staff by April of 2002.

<u>Further Important Considerations</u>

Beyond the options recommended above, the possible loss of power plant waste heat at the Elmendorf SFH must also be considered. A contractor is currently evaluating whether the Elmendorf Air Force Base power plant should remain in operation or be shut down. The decision to remain operating or close the Elmendorf base's power plant will not be made until late 2002 and it would take the base at least three years to develop a distributed heating system. Therefore, Elmendorf SFH may also be facing lost production capacity by 2005 if their inexpensive source of waste heat is lost. Even when considering the options proposed here, the current fish production requirements of the Alaska Department of Fish and Game could not be met if the waste heat supplied to the Elmendorf power plant was also lost. In this event, it is recommended that the Alaska Department of Fish and Game consider closing either Fort Richardson or Elmendorf SFH and building a new hatchery to handle all production that cannot be met by the remaining hatchery. This conclusion is nearly inescapable if both hatcheries end up losing their source of inexpensive waste heat. It is recommended that a new hatchery would be designed to operate on a well water supply and would use tank-based recirculating systems to minimize water use, heat input requirements, and environmental impact on the receiving water. It is estimated that a new state-of-the-art hatchery would cost $9–16 million. If this kind of capital funding can be obtained, it is recommended that this new hatchery be built at an inland location with convenient access to stocking sites. The location selected for a new hatchery would have to include suitable well water resources (at least 1,000 gpm of high quality ground water), good road access, 3-phase power, natural gas, and telephone service, as well as available public sewer connections if septic tanks and leach fields are not permitted.

It is our opinion that continued operation of either the Fort Richardson or Elmendorf SFH is essential to maintain the public education and outreach that is achieved when approximately 10,000 visitors per year visit the Elmendorf SFH. The ease of access to the Elmendorf SFH is a major reason to choose to keep Elmendorf SFH open and close the Fort Richardson SFH in the event that both hatcheries lose their access to inexpensive waste heat. Access to Elmendorf SFH is easier than for Fort Richardson SFH because the Elmendorf SFH is closer to Anchorage and visitors do not have to enter a military base to enter the Elmendorf SFH. Entry to the Fort Richardson SFH is more restricted because it is further away and located on the Fort Richardson base.

If Fort Richardson SFH were closed, then it would be essential that the Alaska Department of Fish and Game implement at least some of the improvements recommended in the accompanying Elmendorf SFH Report. Also, it is not recommended that the Alaska Department of Fish and Game invest in all of the improvements suggested above for the Fort Richardson SFH if this hatchery were to be closed by 2005, because the cost of these upgrades could exceed $5 million.